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A Conceptual Analysis of Technological Pedagogical Content Knowledge

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A CONCEPTUAL ANALYSIS OF TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE

by

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GRADUATE COMMITTEE APPROVAL

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This dissertation has been read by each member of the following graduate committee and by majority vote has been found to be satisfactory.

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As chair of the candidate's graduate committee, I have read the dissertation of Suzy Cox in its final form and have found that (1) its format, citations, and bibliographical style are consistent and acceptable and fulfill university and department style requirements; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the graduate committee and is ready for submission to the university library.

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ABSTRACT

A CONCEPTUAL ANALYSIS OF TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE

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Doctor of Philosophy

This dissertation reports the results of a conceptual analysis of the technological pedagogical content knowledge (TPACK) framework, particularly its component constructs of technological content knowledge (TCK), technological pedagogical knowledge (TPK), and TPACK (the central component of the framework listed earlier). First, a technical use analysis reveals how existing research has defined and exemplified the constructs. Next, interviews with leading TPACK researchers further refine the constructs. The dissertation then reports cases that illustrate each of the constructs and the boundaries between them. The conceptual analysis results in an elaborated model of the TPACK framework, focusing on the essential features of each construct to facilitate classification of future examples. The analysis also reveals that TCK, TPK, and TPACK do appear to be distinct constructs. The boundaries among constructs are elaborated through a discussion of the sliding nature of the framework and the nature of the instructional strategies that are enacted.

ACKNOWLEDGEMENTS

As a wife, mother, and teacher, this journey has been a long and trying one. Life for the past few years has seemed to be a constant compromise, a trade-off between my life and my work. I don't know that anyone can fully understand the difficulty of this road except for the other women who have trodden it. I could not have made it to the end without the support of the following individuals.

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Thanks also to my father, who has believed in me from the day I was born and who taught me to think for myself; my brother, Mike, a friend, sounding board, and commiserater for over 30 years; Dr. Summer Rupper, a source of inspiration and friendship and the twin from whom I was separated at birth; and my mother: without you, this never would have happened. My children have felt safe and loved because of you and I thank you from the bottom of my heart.

I dedicate this work to my children, Brighton and Katy. They have endured more "in-a-minute"s than any children should have to. They are intelligent and beautiful and wonderful and I hope that they always remember how strongly their mother believed in education. But most of

all, I dedicate this dissertation to my husband, Ryan, who never stopped believing in my ability to do this and be everything else too. I love you. Thank you.

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CHAPTER 1: INTRODUCTION

In 2005, Punya Mishra and Matthew Koehler introduced a new theoretical framework known as Technological Pedagogical Content Knowledge (TPACK). The basic premise of TPACK is that a teacher's knowledge regarding technology is multifaceted and that the optimal mix for the classroom is a balanced combination of technology, pedagogy, and content. TPACK has been received with tremendous support in the instructional technology community, with an entire thread devoted to it at the 2007 and 2008 International Conferences of the Society for Information Technology and Teacher Education.

The TPACK framework was built on the idea of pedagogical content knowledge (PCK) proposed by Schulman in 1986. The foundation of PCK is that general pedagogical knowledge and knowledge about content exist independently, but the overlap of these two knowledge domains creates a new type of knowledge—how to teach particular subject matter content—that is unique to teachers. This idea has been somewhat controversial and very difficult for researchers to study in that it involves tacit knowledge rather than behaviors, making it difficult to observe or measure. In fact, recent research at the University of Michigan is beginning to reveal that pedagogical content knowledge either is not a valid construct or cannot be differentiated from pedagogical knowledge or content knowledge with quantitative measures. Nevertheless, the pedagogical content knowledge framework has proven a valuable one for the study of teaching and teacher education. Mishra and Koehler's framework assumes the validity of Schulman's model and builds on it, adding the new dimension of technology.

The original Schulman model proposed that there is a certain domain of knowledge involving both an understanding of pedagogy (teaching methods, child development, motivation, student needs and behaviors, etc.) as well as an understanding of the content being taught (see Figure 1.1).

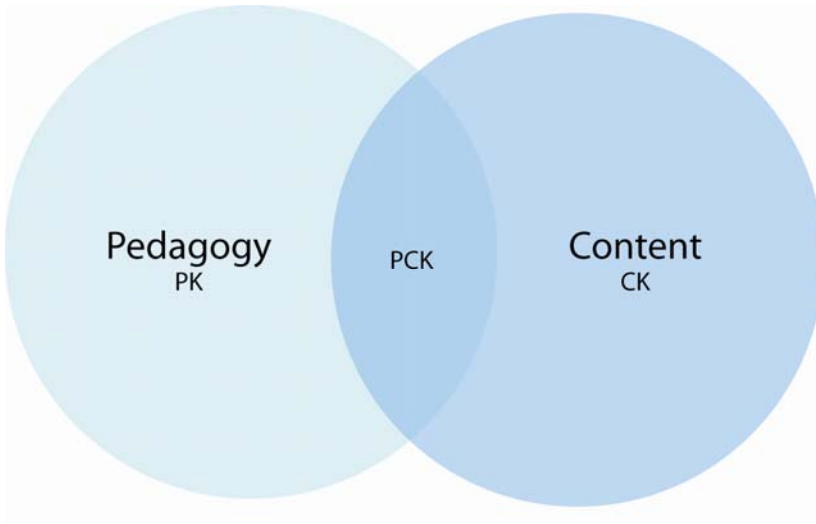

Figure 1.1. Pedagogical Content Knowledge

Mishra and Koehler's framework adds the domain of technology, creating three new combined constructs, namely; TPCK, technological content knowledge (TCK), and technological pedagogical knowledge (TPK) as shown in Figure 1.2.

Statement of the Problem

While Koehler, Mishra, and others have attempted to define and measure TPACK, the framework is not yet fully understood. To this point, the majority of studies conducted on TPACK have involved extensive observations and interviews to illuminate the development of TPACK in various contexts—from pre-service teacher education programs to graduate seminars and in-service practice. All of these studies have been based on the assumption that TPACK exists, which has not yet been substantiated through research. These studies utilize differing criteria in their search for evidence of TPACK and the scale of the research is not easily replicable. They also reveal that the construct is difficult to implement and to measure. All of these studies have been examining only the development of TPACK.

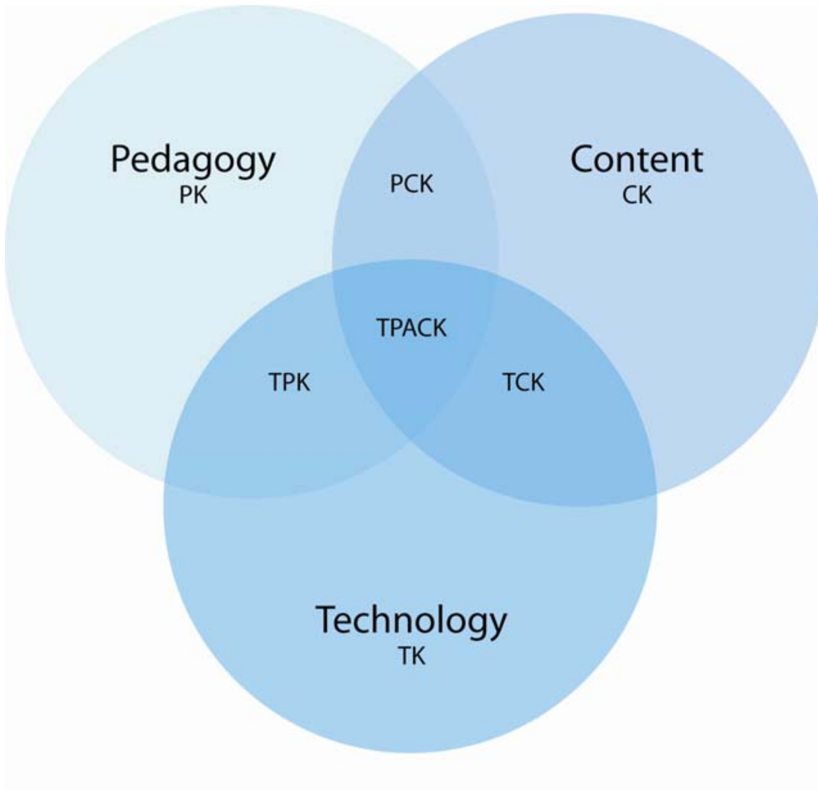

Figure 1.2. Koehler and Mishra's Technological Pedagogical Content Knowledge Framework

Even without clear support for the framework, Mishra and Koehler somewhat boldly proposed additional constructs (TCK and TPK) within their framework, none of which are backed by empirical evidence and none of which have yet been fully defined or explored. While Mishra and Koehler provide basic definitions and some examples for each of the constructs, they do not provide evidence of their existence.

Statement of Purpose

The purpose of this study was to seek definitions of and evidence for the component constructs of the TPACK model, particularly (a) technological content knowledge, (b) technological pedagogical knowledge, and (c) technological pedagogical content knowledge. I chose to focus on these constructs because they are unique to the TPACK framework and have not yet been analyzed thoroughly as PK, CK, PCK, and TK have been. I used the techniques of conceptual analysis to identify the essential features of and relationships between TCK, TPK, and TPACK. Additionally, determining the essential features of each construct helped to reveal whether each construct represents a distinct type of knowledge and also allowed me to classify and craft examples of each.

This study will make a valuable contribution to the study of technological pedagogical content knowledge in that it provides clearer descriptions of each of the constructs, allowing for more fruitful future research to be conducted in this area.

Research Objectives

This study was directed by the following objectives:

1. Create precising definitions of technological content knowledge, technological pedagogical knowledge, and technological pedagogical content knowledge based on evidence from a conceptual analysis.
2. Elaborate examples of each construct.
3. Demonstrate the similarities and distinctions between these constructs through a graphic organizer.

CHAPTER 2: REVIEW OF RELATED LITERATURE

In order to explore the components of the TPACK framework, I needed to first understand its origins in the pedagogical content knowledge paradigm introduced by Shulman, then explore what Koehler and Mishra and others have discovered with regard to TPACK. Finally, I needed to elucidate the purposes and methods of conceptual analysis and its background in logic in preparation for the full explanation of this study.

Pedagogical Content Knowledge

The knowledge required for teachers has varied greatly throughout history. The ability to teach one's subject was requisite for an advanced degree at the great Parisian institutions of the 1500s (Ong, 1958). Students were presented an integrated curriculum of pedagogy and subject matter. By the late 1800s, the focus had turned almost completely to subject matter knowledge—it was sufficient for a teacher to know more about a subject than his/her students.

By the mid-1980s, the emphasis of teacher training had swung almost completely toward pedagogy, leaving content knowledge ancillary to teaching methods (Shulman, 1986). In 1986, Shulman proposed that it wasn't enough to teach content and pedagogy as two separate entities; that, in fact, good teaching required a complex integration and balance of the two. Shulman proposed that different content areas required different methods of inquiry and instruction. This new and somewhat controversial (Deng, 2007) idea of pedagogical content knowledge has since become one of the most widely referenced ideas in educational literature (Segall, 2004).

The Origin of the PCK Framework

The concept of pedagogical content knowledge had both theoretical and political origins. Shulman felt a need to demonstrate the importance of subject matter knowledge in training teachers, but there were also external entities, the then Secretary of Education William Bennett being one, who believed that teacher training was unnecessary and that anyone with a college degree could be an educator. The implication of this belief was that teacher knowledge was no different than practitioner knowledge. Thus, the pressure to demonstrate the existence of specialized, professional knowledge in teaching was intense.

Shulman first introduced the term *pedagogical content knowledge* during his President's Address to the American Educational Research Association in 1985 and it first appeared in print in 1986 (Van Driel, Veal, & Janssen, 2001). When the framework was first introduced, pedagogical content knowledge was considered a sub-category of content knowledge, demonstrating Shulman's emphasis on subject-matter knowledge in teaching (Shulman, 1986). Later representations brought it to the fore, with Shulman listing pedagogical content knowledge as one of seven "components of the professional knowledge base of teaching" in 1987. This model was later pared to represent pedagogical content knowledge as an amalgamation of one's knowledge of content and general pedagogical knowledge in a given context (Grossman, 1990). This version of the framework has served as the foundation for extensive research in the field of education (Gess-Newsome, 1999). It is this framework from which TPCK was built and, therefore, it deserves closer examination and explication.

Elaboration of the PCK Framework

In 1990, Pamela Grossman, a former graduate student of Shulman's, codified what came to be the most widely accepted description of pedagogical content knowledge. Grossman elaborated four general areas of teacher knowledge, as follows: (a) subject matter knowledge, (b) general pedagogical knowledge, (c) knowledge of context, and (d) pedagogical content knowledge. By detailing these elements of pedagogical content knowledge, Grossman reveals the complexity of the construct. These areas of teacher knowledge will be explained in the following paragraphs.

Subject matter knowledge includes an understanding of the major facts and concepts in a discipline as well as the substantive and syntactic structures of that field. Substantive structures include the major paradigms that influence the organization of the discipline as well as its methods and topics of inquiry. Syntactic structures are those rules and systems that regulate the creation or evaluation of new knowledge within a discipline.

General pedagogical knowledge is what one commonly envisions when considering the content of a teacher education program. It includes general skills, beliefs, and knowledge related to teaching, regardless of a particular subject area. Knowledge and beliefs about learners, basic principles of instruction, classroom management, and the aims and purposes of education are all part of general pedagogical knowledge.

Knowledge of context relates to an understanding of the particularities of the specific setting in which an educator is situated. This includes an understanding of the district, the school, the community, and the students.

Definitions of the PCK Framework

While each of these areas of knowledge is complex and nuanced, pedagogical content knowledge is perhaps even more so as it is considered an amalgamation of a number of component knowledge types. Shulman originally defined pedagogical content knowledge as "the particular form of content knowledge that embodies the aspects of content most germane to its teachability" (1986). Shulman elaborated on that definition as follows:

> Within the category of pedagogical content knowledge I include, for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas,

> the most powerful analogies, illustrations, examples, explanations, and demonstrations – in a word, the ways of representing and formulating the subject that make it comprehensible to others….Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons. (p. 9)

Shuman expanded the definition later by stating that "this knowledge includes an understanding of what it means to teach a particular topic as well as knowledge of the principles and techniques required to do so" (Wilson, Shulman, & Richert, 1987, p. 118). Shulman went on to suggest that, rather than existing as separate domains of knowledge, pedagogical content knowledge is actually a transformation of subject matter knowledge, general pedagogical knowledge, and knowledge of context, creating a new form of knowledge that is unique to teachers. Additionally, the relationship between these forms of knowledge is bidirectional, meaning that each type of knowledge both contributes to and is derived from pedagogical content knowledge (see Figure 2.1).

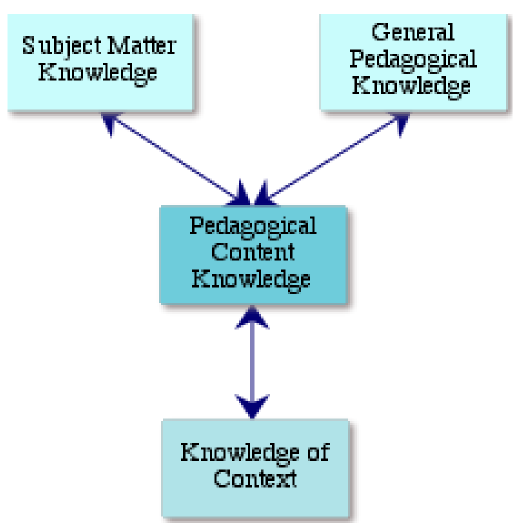

Figure 2.1. Relationship between the four general areas of teacher knowledge.

Grossman further illuminates Shulman's construct by describing what she calls "four central components" (1990, p. 8). The first of these components "includes knowledge and beliefs about the purposes for teaching a subject at different grade levels" (Grossman, 1990, p. 8). Researchers in science education refer to this component as one's "orientation toward teaching" (Magnusson, Krajcik, & Borko, 1999, p. 97; Anderson & Smith, 1987). This component includes a teacher's beliefs about why a subject is important for students at a particular grade level and that teacher's purposes and goals for teaching the content. This orientation generally serves as an overarching guide for instructional decisionmaking.

The second of Grossman's components refers to students' understanding of particular topics in the subject matter. This component includes an understanding of students' prerequisite knowledge in the subject as well as the topics that students generally struggle with. Put more succinctly, it "includes knowledge of students' understanding, conceptions, and misconceptions of particular topics in a subject matter" (Grossman, 1990, p. 8).

The third component described by Grossman involves curricular knowledge. Shulman originally identified this domain as a separate type of content knowledge and defined it as an awareness of "the full range of programs designed for the teaching of particular subjects and topics at a given level, the variety of instructional materials available in relation to those programs, and the set of characteristics that serve as both the indications and contraindications for the use of particular curriculum or program materials in particular circumstances (1986, p. 10). Grossman reduced this definition to two components: an understanding of the available materials for teaching a topic and "knowledge about both the horizontal and vertical curricula for a subject" (1990, p. 8). *Horizontal curricula* refers to the content and skills being learned by students in other classes at a given time; and awareness of the overall educational objectives at a given grade level. *Vertical curricula* describes an understanding of the curriculum for a given subject across grade levels. In other words, an effective teacher should be able to perceive the context of his/her class, both long-term and short-term.

The final component proposed by Grossman is a "knowledge of instructional strategies and representations for teaching particular topics" (1990, p. 9). Magnusson, Krajcik, and Borko here differentiate between subject-specific and topic-specific instructional strategies, noting that there are broad strategies that are generally accepted by a particular discipline, but there are also strategies with a very narrow scope that apply only to the teaching of a particular topic (1999). With regard to representations, Grossman notes that "experienced teachers may possess rich repertoires of metaphors, experiments, activities, or explanations that are particularly effective for teaching a particular topic" (1990, p. 9). Based on such a statement, some have reduced the concept of pedagogical content knowledge to the idea that a series of effective representations is all that is needed to teach a subject well, perhaps resulting in the movement toward learning objects in the late 1990s. However, Shulman's original proposal contradicts this theory, stating that "pedagogical content knowledge is not simply a repertoire of multiple representations of the subject matter. It is characterized by a way of thinking that facilitates the generation of these transformations, the development of *pedagogical reasoning*" (1987, p. 115, emphasis in the original).

Tamir (1988) proposed a fifth component of pedagogical content knowledge, namely, knowledge and beliefs about assessment. This component is seen as having two facets: an understanding of what to assess and an understanding of how to assess (Magnusson, Krajcik, & Borko, 1999). The relationships between PCK and its component knowledge types are once again bidirectional, with each type of knowledge both contributing to and deriving from PCK, as shown in Figure 2.2.

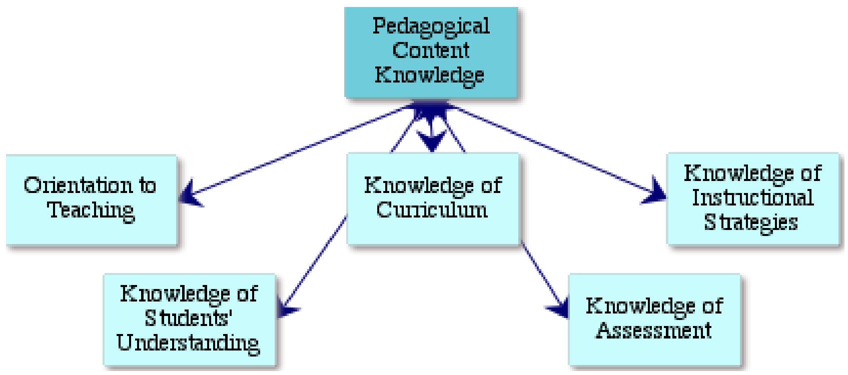

Figure 2.2. Components of pedagogical content knowledge.

Thus, pedagogical content knowledge is a complex construct derived from teachers' subject matter knowledge, general pedagogical knowledge, and knowledge of context and is composed of teachers' orientation to teaching the subject, knowledge of students' understanding, knowledge of the curriculum, knowledge of instructional strategies, and knowledge of assessment.

Controversies Regarding the PCK Framework

Since its introduction in 1986, the pedagogical content knowledge framework has been used as the foundation for numerous educational studies. However, it is certainly not without a degree of controversy. Marks (1990) perhaps described the conflict surrounding this model best with his description of the "blurred boundaries" (p. 9) that exist between pedagogical content knowledge, subject matter knowledge, and general pedagogical knowledge. He lists three ambiguities inherent in any study of pedagogical content knowledge that illustrate these fuzzy demarcations.

First, because pedagogical content knowledge is derived from subject matter knowledge and general pedagogical knowledge, any example of pedagogical content knowledge will necessarily contain features of each. This means that any classification of an item as pedagogical content knowledge is simply “a matter of focus” (Marks, 1990, p. 8). For example, a teacher’s discourse on their use of journal entries to teach about the civil war may be classified as subject matter knowledge if one focuses on the teacher’s understand of history, general pedagogical knowledge if one focuses on the teacher’s understanding of motivation and student learning, or pedagogical content knowledge if one focuses on how the teacher weaves content and pedagogy together in a given context.

Secondly, because these studies take place in an educational context, “statements about subject matter translate directly into pedagogical terms even though they are not expressed in those terms” (p. 8). Thus, a statement about a scientific topic by a teacher can easily be interpreted to be a statement about the teaching of that topic.

Finally, statements made about the teaching of one subject matter can apply to any subject matter. Are these statements, then, representative of pedagogical content knowledge or general pedagogical knowledge?

In addition to the difficulty in distinguishing between the various terms in the framework, determining how and why teachers make decisions, particularly as they happen in the classroom, has always been notoriously difficult (Shulman, 1986). This is particularly true of pedagogical content knowledge as it is both an internal and external construct, making it impossible to observe directly (Baxter & Lederman, 1999). When this difficulty is added to the ambiguities listed above, a clearer picture of the doubts and challenges surrounding pedagogical content knowledge emerges. As stated by Gess-Newsome, “This overlap [of the knowledge bases] demonstrates the difficulty of producing adequate definitions of complex concepts and of establishing clear, discrete, and manageable categories that avail themselves to examination. It also raises questions about this model of teacher knowledge itself” (1999, p. 6). In short, the pedagogical content model is lacking precision.

Some have questioned Shulman’s definition of pedagogical content knowledge as the transformation of subject matter knowledge, general pedagogical knowledge, and knowledge of context into a new form of knowledge that exists independently from those knowledge bases (Carlsen, 1999; Marks, 1990). Instead, researchers suggest the possibility that pedagogical content knowledge is integrated from subject matter, pedagogy, and context in the act of teaching (Gess-Newsome, 1999). This definition paints a much more fluid picture of pedagogical content knowledge that the transformative perspective does. However, does this perspective actually negate the existence of pedagogical content knowledge as a unique construct?

Regardless of the ambiguity surrounding pedagogical content knowledge, the construct has proven very valuable to the field of education. Gess-Newsome lists four contributions of the pedagogical content knowledge framework to the study of teaching, namely, that it has (a) “provided a new analytical frame for organizing and collecting data on teacher cognition, (b) highlighted the importance of subject matter knowledge and its transformation for teaching, (c) incorporated findings across related constructs, and (d) provided for a more integrated vision of teacher knowledge and classroom practice” (1990, p. 9, numbers added). Therefore, though the construct may flawed and/or difficult to measure, it has provided a valuable lens with which to examine teaching.

Technological Pedagogical Content Knowledge

It is upon this imprecise model that the relatively new framework of technological pedagogical content knowledge (TPACK, changed from TPCK [Thompson & Mishra, 2007]) is built, adding the new component of technology to the mix.

The introduction of modern computer technologies has vastly changed the way our students interact and learn as well as their future prospects in terms of skills and job opportunities. Initially, technology was treated similar to how pedagogy was treated in the middle of the last century—as a separate but (perhaps) necessary entity (Mishra & Koehler, 2006). Training preservice teachers in educational technology was not a priority until the mid 1990s (Wentworth & Earle, 2003) and technology has largely been maintained as a separate course in teacher education programs (Graham, Culatta, Pratt, & West, 2004).

Recently, however, a number of researchers have argued that keeping technology separate from content and pedagogy is a disservice to our students and propagates misuse and even disuse of educational technology (Cuban, 2001; Hooper & Rieber, 1995). These researchers have therefore proposed an expansion of Shulman's model to include the domain of technology (Mishra & Koehler, 2006). The overlap of these three domains—content, pedagogy, and technology—is a new framework known as technological pedagogical content knowledge (see Figure 2.3). Though the overlap of the domains was not a completely new concept before Mishra and Koehler's work, they were the first to clearly articulate the interrelationships between the three domains, including the unique pairings that occur between them.

Components of TPACK

The many domains and combinations of domains found in this framework can be confusing, thus a brief summary may be helpful.

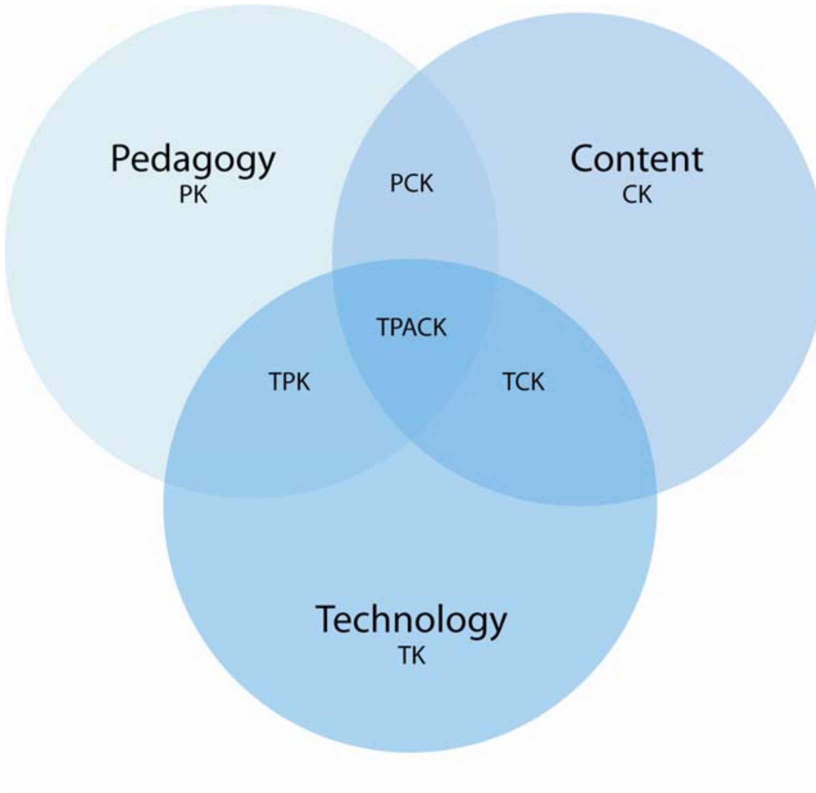

Figure 2.3. Technological Pedagogical Content Knowledge

Content Knowledge (CK) refers to a person's understanding of the concepts related to a specific academic discipline. Additionally, a person with content knowledge also understands the structures of their subject matter (Shulman, 1986). This partition of the framework would refer to tasks like knowing how to write a five paragraph essay, reciting the periodic table of elements, properly solving mathematics problems, etc.

Pedagogical Knowledge (PK) refers to basic, generalizable teaching strategies. According to Morine-Dershimer and Kent (1999) pedagogical knowledge is a combination of many components including classroom management and organization, instructional models and strategies, and classroom communication and discourse. Those researchers also contend that personal beliefs, practical experience, and reflection also play a large role in shaping pedagogical knowledge.

Pedagogical Content Knowledge (PCK), the overlap proposed by Shulman, refers to the idea that pedagogy and content are interwoven. Shulman defines it as "subject matter knowledge *for teaching"* (Shulman, 1986). This domain refers to one's ability to combine teaching methods (PK) and curricular understanding (CK) with knowledge about learners and learning and with an understanding of educational goals and assessment to communicate information effectively and efficiently to students (McCaughtry, 2005; Morine-Dershimer & Kent, 1999). For example, social science teachers use primary-source documents to obtain first-hand accounts of events and to make historical eras come alive.

Technology Knowledge (TK) refers to one's ability to use computer technology—to manipulate programs and hardware to produce desired results. This facet of the framework is completely decontextualized – meaning that anyone in any field of employment, at any age, living anywhere in the world, can possess technology knowledge.

Technology Content Knowledge (TCK) refers to an understanding of which technologies are appropriate to use in various disciplines, whether in the classroom or on the job. Inherent here, too, is the understanding that technology may require a compromise of content or may enhance representation of content (Harris, Mishra, & Koehler, 2007; Mishra & Koehler, 2006). For example, draftsmen use CAD programs to help them complete their projects, and medical doctors use heart monitors to track the progress of their patients.

Technological Pedagogical Knowledge (TPK) refers to a general understanding of the application of technology in education without reference to a specific content. It also includes the ability to creatively use available technology tools in a pedagogical context (Harris et al., 2007).

This domain is apparent in generic treatises on effective technology integration and may include such applications as how to use digital cameras in the classroom or principles of effective distance education.

Technological Pedagogical Content Knowledge (TPACK) refers to the complex interrelationship between a teacher's technology use, instructional methods, and understanding of the subject matter (Mishra & Koehler, 2006). In other words, teachers who possess TPACK think about and use technology as a part and enhancement of their pedagogical methods in teaching content. Thus, the proponents of this model are not asking teachers to develop virtual classrooms controlled completely by machines, but to be aware of ways that technology can support high quality teaching in curriculum areas (Loveless et al., 2001).

The Complexity of TPACK

TPACK is not a simple combination of three independent domains; rather, content, pedagogy, and technology are interdependent, each one affecting the others (Harris et al., 2007). The choice of content affects the pedagogical goals and methods as well as the technologies used; the technology used comes with certain limitations, requirements, or features that may affect which content is covered or how it will be taught (Mishra, Koehler et al., 2007). Utilizing the TPACK framework can drastically change the way teachers teach their subjects (Swenson, Young, McGrail, Rozema, & Whitin, 2006). Additionally, TPACK has been found to improve teachers' cultural sensitivity (Kelly, 2007; Lambert & Sanchez, 2007). Mishra and Foster also argue that TPACK would improve the quality of educational games (Mishra & Foster, 2007).

Understanding how to balance all three domains in a way that is most effective for learners is a difficult skill to acquire (Bull et al., 2007). True TPACK is particularly difficult to master first because of the complex relationships and also because of the continually changing nature of technology, making every technology integration problem a unique one (Koehler & Mishra, in press; Mishra & Koehler, 2007). This means that simply teaching teachnology skill is not enough (Koehler & Mishra, in press).

Teacher educators are beginning to stress the need for TPACK development in preservice programs (Niess, 2006; van Olphen, 2007). Thompson (2005) indicates that TPACK will have a profound impact on preservice teacher education. Mishra and Koehler contend that TPACK is best developed in a context of *learning technology by design* (Koehler & Mishra, 2005a; Mishra & Koehler, 2003; 2006). This approach to instruction is based on the idea "that the design of educational technology represented an authentic context for teachers to learn about educational technology" (Mishra & Koehler, 2006, p. 1034). Design in this context requires participants to weave technology, content, and pedagogy together to create an open-ended final project (Mishra & Koehler, 2005).

Researchers have made various attempts at measuring the development of TPACK in these *learning technology by design* course experiences. Predominant in the methods of these studies is the use of document analysis–using projects, progress reports, recorded interviews, papers, observation field notes, etc., to monitor students' progress (Koehler, Mishra, Hershey, & Peruski, 2004; Koehler, Mishra, & Yahya, 2007). Some researchers have also now ventured into using a survey instrument to track TPACK development (Koehler & Mishra, 2005b; Mishra & Koehler, 2005; Cox, Graham, Browne, & Sudweeks, in review). Mishra and Koehler's survey required groups and individuals to answer questions about where their thoughts were centered (content, pedagogy, or technology) during a design project. The survey by Cox et al. attempted to measure preservice teachers' self-efficacy in performing TPACK-related tasks.

Holes in the TPACK Research

The implementation of this framework in teacher education has been limited, in large part, to the original TPACK theorists' own experiments with graduate student seminars. This may be due to the fact that the framework has largely remained in the theoretical realm with no clear method for implementation or evaluation. Koehler and Mishra's studies have involved graduate students working with faculty on a single project over the course of a semester that involves faculty-directed content without any requirements or restrictions on the end product—a model which is not feasible or appropriate for a preservice course (Koehler & Mishra, 2005a, 2005b; Koehler et al., 2004; Koehler et al., 2007; Mishra & Koehler, 2005; Mishra, Koehler et al., 2007).

Beyond Koehler and Mishra's studies, the body of research on TPACK is varied. Studies on TPACK development have been conducted with in-service school teachers (Harris et al., 2007; Lambert & Sanchez, 2007; Murphy, 2007; Niess, 2007; Rodrigues, Marks, & Steel, 2003; Wellman & Snow, 2007) and university faculty (Dong & Sun, 2007; Peruski, Mishra, & Koehler, 2007; Sun & Deng, 2007) as well as with graduate preservice teachers (Cordivari, Holland, & Ours, 2007; Niess, 2005). Several studies have also been conducted with preservice teachers but have been purely descriptive (Burns, 2007; McCormick & Thomann, 2007), have taken place in a methods or other program course not related to technology (McCormick & Thomann, 2007; Shoffner, 2007; Suharwoto, 2006; Suharwoto & Lee, 2005), or have either been too detailed to be replicable or too simplistic to be truly valuable (Cavin & Fernandez, 2007; Fapojuwo, 2007). One study involved a course with projects using required technologies that rated projects on a TPACK-oriented scale (Angeli & Valanides, 2005). However, all of these studies have been based on the assumption that TPACK exists and is a measurable construct.

None of them has analyzed the component constructs, namely technological pedagogical knowledge (TPK) and technological content knowledge (TCK) suggested in Koehler and Mishra's framework. Further, none have attempted to fully define and exemplify each of the constructs in the model.

Conceptual Analysis

The research about PCK began in much the same way as the research surrounding TPACK, with researchers assuming the legitimacy of the construct rather than illuminating it (Marks, 1990). Thus, numerous studies have been conducted that are based on the framework, but none have been conducted which actually help to define and critically analyze it. Coombs and Daniels maintain that this is not an unusual phenomenon in educational research, stating that "social scientists often propose interpretations without attempting to understand fully the use or meaning of the concepts they are interpreting" (1991, p. 28). In order for this framework to become a useful research tool, those using it must be able to accurately measure the construct. In order to measure the constructs, researchers must be able to consistently define each of them and differentiate between them conceptually.

This study was conducted using conceptual analysis. Conceptual analysis, or philosophical inquiry, refers to a loose set of techniques with which scholars attempt to elucidate the meanings of words and concepts as a basis for future research and understanding (Coombs & Daniels, 1991; Soltis, 1978; Wilson, 1963). The point of any conceptual analysis is to explain a concept to the degree that a given individual can understand it (Soltis, 1978) and the need for a conceptual analysis typically springs from someone asking questions such as, "What does X mean?" or "What is an example of X?"

The techniques of conceptual analysis are based in the field of logic, particularly in that conceptual analysis involves the search for definition. Aristotle defined *definition* as “a phrase indicating the essence of something” (as cited in Parry, 1991, p. 80). There are many types of definition that might provide that essence. In this study, the objective is a precising definition—one which draws from typical usage of the term and to clarify the meaning of that term (Copi & Cohen, 1990). To create a precising definition, the researcher must “remain true to established usage” while going beyond that usage to illuminate the concept (Copi & Cohen, 1990), usually by outlining further properties of the concept that have not been specified in prior usage (Parry & Hacker, 1991). The purpose of a precising definition is to draw “more sharply the boundary between what does and what does not fall under a concept” (Parry & Hacker, 1991, p. 93). The danger in defining others’ terms is that the researcher may go too far (Beardsley, 1966), so this elaboration must be done very carefully. Thus, the researcher reviewed her definitions and conclusions with TPACK experts and tested the definitions through examples (Beardsley, 1966). The true test of a precising definition is its utility in classifying borderline cases (Copi & Cohen, 1990), one of the recommended techniques of conceptual analysis.

In the case of this study, I attempted to understand the meaning of *technological pedagogical content knowledge* and its affiliated constructs and, particularly, the features that distinguish one construct from another. Conceptual analysis allows me to do this. Thus far, the explanations of technological pedagogical content knowledge that have been provided are not clear enough for even experts to agree on what is and is not an example of that concept (M. Neiss, personal communication, 2007). While Mishra and Koehler and others have provided definitions of each construct that articulate to some degree the centers of these constructs, the boundaries between them are still quite fuzzy, thus making it difficult to categorize borderline cases.

According to Coombs and Daniels, there are two situations in which in-depth conceptual analysis is necessary. The first situation is when the researcher is dealing with a complex concept. The second is when an accurate description of the concept is necessary in order for others to conduct fruitful research (1991). Both conditions are met in the analysis of technological pedagogical content knowledge. As illustrated earlier in the review of pedagogical content knowledge, this area of study is very complex and the boundaries between the internal constructs are “blurred.” Additionally, in order for TPACK researchers to be able to draw valuable conclusions from their studies, they must have a better understanding of the concept and its components.

CHAPTER 3: METHOD

The decision to conduct a conceptual analysis of the TPACK framework was inspired by three distinct events. First, in conducting a literature review on TPACK, I noticed that different writers seemed to define TPACK differently. One particular example of that phenomenon was a presentation given at the 2007 International Conference for the Society for Information Technology and Teacher Education (SITE). This conference presentation was given by a teacher educator who claimed that she had been building students' TPACK in her technology integration course for years. She then went on to outline a course that looked much like the typical instructional technology course with some direct instruction and some projects emphasizing core curriculum—a model that I had used in my own classes and classified as building TPK rather than TPACK. This experience revealed that the existing definitions of the TPACK constructs were not reliable.

Next, I found that more clarification was needed as I endeavored to devise a way to measure TPACK with a questionnaire and I engaged in discourse with Margaret Niess at Oregon State University, a known TPACK researcher. After I had coded the items in a particular instrument according to the TPACK framework, Dr. Niess reviewed the codings and found issue with some of them, prompting a discussion on the difficulty of classifying examples as belonging to one or another of the constructs (M. Niess, personal communication, 2007).

Finally, after completing a trial of an instrument intended to measure TK, TCK, TPK, and TPACK and conducting a principal components analysis on the survey items, I found that, rather than loading on four or five factors as would be expected, the items primarily loaded on two factors (Cox, Graham, Browne, & Sudweeks). Thus, I determined to postpone further experimentation with the survey instrument in order to complete a conceptual analysis that would clarify the framework.

Planned Methodology

The techniques of conceptual analysis are not dictated by any set of precisely-defined rules or procedures, rather, they consist of a loose set of guidelines that can be adapted to the context of the analysis. For this particular research context, I chose to implement five techniques: (a) technical use analysis, (b) model cases, (c) contrary and related cases, (d) borderline cases, and (e) invented cases. The planned results of these techniques were precising definitions for TCK, TPK, and TPACK as well as a graphic organizer to assist in visualizing the relationships and distinctions between the constructs. Figure 3.1 illustrates the techniques that were utilized in the conceptual analysis as well as the anticipated outcomes.

The following sections elaborate on the techniques of this conceptual analysis as they were originally planned, namely, the technical use analysis, model cases, contrary and related cases, borderline cases, and invented cases. Additionally, the purpose and nature of the graphic organizer are described. While the methods described here seem fairly discrete and linear, the reality of the conceptual analysis was much more iterative in nature. Thus, the description of the planned methodology is followed by a narrative of the actual process for the study.

Phase 1: Technical Use Analysis

The intended starting point for this study was a technical use analysis of technological pedagogical content knowledge and its affiliated constructs. The questions in need of answers included the following:

1. How had Koehler and Mishra defined the concepts?
2. How had other researchers interpreted them in their studies?

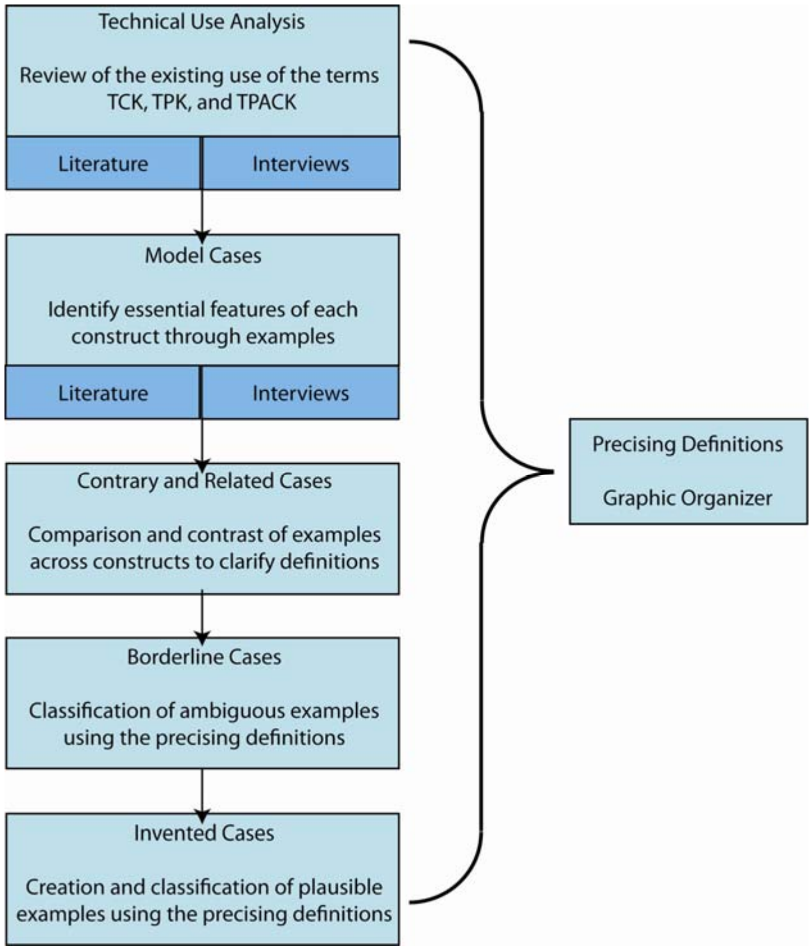

Figure 3.1. Summary illustration of conceptual analysis techniques used in this dissertation.

A thorough examination of existing TPACK literature would provide a broad view of the use of the conceptual terms in the research, illuminating conflicting or unclear interpretations (Coombs & Daniels, 1991) and giving rise to the beginnings of a description of the concepts. In other words, I needed "to find out what the various users of the technical concepts mean by them" (Coombs & Daniels, 1991, p. 34)

I planned to begin the technical use analysis by examining the definitions for each of the constructs as provided by Mishra and Koehler (2006). These definitions would "provide good initial hypotheses about the meaning of the term[s]." According to Coombs and Daniels, "[They] should not be regarded as authoritative, however, because educational theorists and researchers often give very inaccurate accounts of how their technical terms are being used" (Coombs & Daniels, 1991, p. 34). I would then review the examples and definitions of the constructs provided by other researchers. The intended result of the technical use analysis was a set of precising definitions for the constructs.

Phase 2: Model Cases

The next step in a thorough conceptual analysis includes finding model cases which exhibit the essential features of the concept (Wilson, 1963). For my study, this step meant finding cases that exemplified technological content knowledge, additional cases that exemplified technological pedagogical knowledge, and other cases that exemplified technological pedagogical content knowledge

I intended to first conduct interviews with prominent TPACK researchers as well as an elementary teacher and a university professor to gather model examples of each of the constructs. Interviewees were to be selected using maximum variation sampling (Patton, 1990).The TPACK researchers had expertise in a variety of subject areas, demonstrating conceptual knowledge of the TPACK framework across disciplines. I chose to interview an elementary school teacher and a university professor to obtain examples that were very different from each other in content and complexity.

The interviews were semi-structured with some prepared questions to guide the overall discussion but with flexibility so that I could pursue topics of particular interest to the study, specifically where the study related to the interviewee's field of specialization (see Appendix A). I planned to record and transcribe the interviews for analysis. Participants' responses would then be compared with the descriptions of each of the constructs generated from the technical use analysis.

It was expected that the interviews with the university professor would yield insight into the technological content knowledge construct whereas the interviews with the elementary teacher would help to illustrate the distinction between technological pedagogical knowledge and TPCK. The interview with the university professor would include questions regarding her use of technology in her field, technologies that are unique to her field, and reasons why those technologies are used. It was anticipated that this interview would help to establish a definition of TCK. The elementary teacher interview would include questions regarding how he uses technology in his preparation and instruction, which technologies he uses and why, and how he uses technology to represent difficult content. It was expected that this interview would illuminate the TPK construct. It was also hoped that the interview might provide examples of the TPACK construct, allowing me to compare these two closely related concepts.

I then planned to search scholarly journals, trade magazines, and online magazines for model cases, finding several ideal cases for each construct. These cases would help me to further clarify the definitions for each of the constructs.

Phase 3: Contrary and Related Cases

Next, I planned to compare the model cases found for each construct with those from the other constructs to determine areas of overlap and to further clarify the defining attributes of each class. Coombs and Daniels (1991) stated that "when one has arrived at tentative conclusions, it is important to test these hypotheses by making a careful search for counter-examples, and to revise them appropriately to take account of the counter-examples" (p. 32). The purpose of the contrary and related cases phase of the analysis was to elucidate the similarities and differences between the constructs, helping me to more precisely determine the boundaries between them.

Phase 4: Borderline Cases

With these newly clarified definitions, I would then review the journals and trade magazines again for cases which were previously difficult to classify as belonging to one construct or another. I anticipated that there would be numerous examples in the literature that could not be classified as belonging exclusively to one construct or another. These borderline cases would serve to test the definitions and boundaries of the constructs. The attempt to classify these borderline cases would help me to further hone the definition of each construct.

Phase 5: Invented Cases

Finally, I planned to craft hypothetical examples of technology and teaching situations that exemplified each of the constructs. These invented cases would enable me to describe each construct in the TPACK framework as a unique form of knowledge within a given context. The invented cases would also serve to fill in examples where the literature was lacking. I planned to distribute the resulting collection of model, borderline, and invented cases to TPACK researchers for their feedback. I was particularly interested in discovering the researchers' level of agreement with the classification of the examples as belonging to one or another of the constructs. Their agreement would provide evidence for the usefulness of the definitions and essential features that I had crafted.

Phase 6: Graphic Organizer

Having completed the conceptual analysis, I planned to create a graphic organizer illustrating the defining features of and relationships between each of the constructs. This graphic organizer would visually represent the precising definitions of TCK, TPK, and TPACK that I had created and highlight the distinctions and relationships between each of the constructs. Having a visual representation of the relationships between the constructs is integral to the future development of measurement instruments or classifications of performances in this area.

Process

While the techniques described above are separated into discrete phases, performing a conceptual analysis is much more of an iterative process in which each step brings new insights and conclusions. This makes the traditional dissertation format somewhat unwieldy in that it is difficult to demonstrate each of the methods used in an orderly fashion. Thus, the remainder of this chapter will serve to illustrate the questions, discussions, struggles, and insights that occurred in each phase of the conceptual analysis whereas the remaining chapters will allow me to summarize the final outcomes of the study.

Preceding Discussion

Before the conceptual analysis began, my advisor and I had several discussions about the TPACK framework, attempting to understand how to categorize examples under each construct. One of the major themes that emerged in those discussions was that of pedagogical strategies, namely, that different types of instructional strategies might play a role in distinguishing between examples of TPK and TPACK.

In our discussions, we identified three types of instructional strategies: (a) general instructional strategies, (b) content-specific general strategies, and (c) content-specific strategies. We thought that, perhaps, TPK would involve the use of generic instructional strategies while TPACK would include both content-specific general strategies and content-specific strategies. General instructional strategies were identified as strategies that could be used across subject areas, such as cooperative learning, problem-based learning, classroom management, and motivation. Content-specific general strategies were defined as strategies that could be used to teach many topics within a given discipline, such as inquiry learning in science, investigations in mathematics, or primary source research in social science. Content-specific strategies referred to specific techniques for teaching a particular topic within a discipline. The theme of instructional strategies would prove to be a central one as the conceptual analysis progressed.

Technical Use Analysis

But before our theory about instructional strategies could be examined further, I needed to better understand the existing literature on TPACK, particularly the definitions and examples that others had given for each of the constructs. I made the decision to focus this review on the TCK, TPK, and TPACK constructs. Each of the main areas—technological knowledge, pedagogical knowledge, and content knowledge—is extremely broad and I did not believe that they needed to be treated in depth in the conceptual analysis. Pedagogical content knowledge plays a major role in TPACK, but I decided not to include this construct in the conceptual analysis as others have already done that work. Each of the constructs was included in the final discussion and the graphic organizer, however.

The first important step in clarifying the concepts of technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPACK) was to determine how each of the terms have been previously used in the published literature. The primary resources for this technical use analysis were the recently published *Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators* as well as the Proceedings of the International Conference of the Society for Information Technology and Teacher Education for 2007 and 2008. Additional articles from my literature review on TPACK were also utilized.

To complete the technical use analysis, I read through each resource making note of definitions of each of the constructs (see Appendix B). For this analysis, only phrases that were explicitly used to define or describe the constructs were chosen. After compiling these definitions, I analyzed each definition for its essential features. I then compared the definitions to look for common attributes as well as differences. I followed the examination of definitions with a review of the examples of each construct provided in the same resources (see Appendix C). Finally, I conducted interviews with seven leading TPACK researchers to clarify questions that I still had about the framework and to revise the conclusions I had made. These discussions were based on semi-structured interview protocols I had created (see Appendix A) and centered around a summary of my questions and conclusions from the technical use analysis (see Appendix D). While I had originally intended to create precising definitions for each of the constructs after the technical use analysis, I found that it was more appropriate at that time to create expansive definitions that captured the complexity of the relationships involved in each construct. The full results of this technical use analysis are included in Chapter 4 of this dissertation.

Analysis of Cases

Completing the technical use analysis allowed me to see how others had used and understood the constructs in the TPACK framework. The second phase of this conceptual analysis involved finding cases that embodied each construct. This was done in three parts: first, examples were gleaned from the resources used in the technical use analysis; second, TPACK experts and educators were interviewed to determine further examples; finally, journals, trade magazines, and the Internet were searched for examples of technology use outside of the TPACK literature. Several examples were found on Edutopia.org, a website created by The George Lucas

Educational Foundation that features spotlights on technology use in education. The Edutopia site was chosen for examples because many of the articles featured there provide first-hand accounts of the technology use by the teachers, including their reasoning for including the technology in their pedagogy.

Analyzing the model cases, contrary and related cases, borderline cases, and invented cases did not take place in discrete phases as was planned. Rather, the search for model cases naturally resulted in the comparison and supplementation required by the other phases. Thus, a description of the analysis of all of the cases is presented in the following paragraphs.

Finding model cases that fit the needs of this study was somewhat difficult. One thing that I believed to be important in my search for model cases was that those examples be first-person accounts. It seemed that this would be the only way to ensure that the examples portrayed the teacher's knowledge rather than an activity from which I would have to infer that knowledge. While the interviewees had indicated that it would be difficult for a teacher to possess TPK independent of context, it actually proved fairly easy to find examples of that construct. There were many instances of teachers discussing how they use technology to motivate their students, to communicate with them, to present information, and to improve classroom management. This knowledge was often expressed in general terms, particularly by elementary school teachers, though I found examples of junior high and high school teachers with TPK, as well. TPACK examples were similarly easy to find, with numerous examples of teachers talking about specific ways in which they use technology in the classroom.

The hardest construct to find examples for was TCK. It was extremely difficult to find first-person accounts of teachers' knowledge of the relationship between technology and content because the majority of examples of teacher knowledge regarding technology are situated in the classroom. While I was able to find a few examples of teachers' knowledge of how technology can represent content, cases of teacher knowledge of how technology helps to generate new content or how content can transform technology were nearly non-existent.

I compiled the cases that I was able to find and classified them as either model or borderline cases (see Appendix E). Model cases exhibited all of the essential features of the construct in which they were classified but no features of the other constructs. Borderline cases exhibited features that might demonstrate two different types of knowledge. I cited and discussed each case to demonstrate its suitability as a model or borderline case. For each of the borderline cases, I also discussed why it was a borderline case and what would make it a model case of one or another of the constructs.

As I was searching for model and borderline cases, I realized that none of the examples available in the literature demonstrated teacher knowledge of each of the TPACK constructs individually. Therefore, I crafted one invented case that demonstrated each of the constructs. This invented case enabled me to confirm the existence and uniqueness of each construct by illustrating theoretical phases of a teacher's understanding of how to incorporate technology in his instruction.

I then compared the model cases across constructs, completing the contrary and related cases phase of the conceptual analysis. In this phase, comparison of the constructs yielded some clarity on the boundaries between them. However, those boundaries were still fairly fuzzy. For example, the boundary between TCK and TPACK was the presence or lack of pedagogy. The boundary between TPK and TPACK was the presence or lack of content. These boundaries still left a lot of gray area that didn't facilitate the classification of borderline cases. For example, if a teacher uses PowerPoint to give a lecture, what kind of knowledge is that? Because questions like this remained, it was apparent that the expansive definitions created in the technical use analysis needed further clarification..

Attempts and Revisions

After I wrote the first draft of the cases section, my advisor noticed that the definitions demonstrated significant overlap between the constructs and did not provide any clarity on how to distinguish between them. For example, both TPK and TPACK include the use of pedagogical strategies with technology and both TCK and TPACK involve the interaction between content and technology. Therefore, it seemed most beneficial to focus the definitions and essential features on those things that made each construct unique, emphasizing the boundaries between the constructs to facilitate classification of examples. While I acknowledged that each of the constructs within the framework represents a “dynamic, transactional negotiation” (P. Mishra, personal communication, May 2, 2008) between its components, and that each of them represents the complex interaction between technology and some other factor(s), the relationship between the components needed to be simplified to facilitate the clarification of the boundaries between constructs. Therefore, the definitions for each construct were pared back to emphasize the distinctions between them, resulting in simplified precising definitions as described in Chapter 4.

A review of a chapter in the Gess-Newsome and Lederman volume on pedagogical content knowledge referenced in the literature review brought clarity to the discussion of instructional strategies that had been a major focus since the beginning of the study. This chapter referred to two types of pedagogical knowledge that a teacher with PCK might have, namely, content-specific and topic-specific. These categories seemed to agree with what my advisor and I had been considering earlier. We reviewed the examples from the model cases in the TPACK section to determine if they fit within these categories. We determined that we did, in fact, have examples of both content- and topic-specific TPACK.

While TPK includes the use of general pedagogical strategies, instructional strategies that might be included in TPACK are those that are content-specific or topic-specific. Each discipline has certain pedagogical strategies that are unique to that area of study, or content-specific, such as inquiry-based learning in the sciences or primary source research in social studies. These strategies can be used to teach a variety of topics within that subject area, but are not easily adapted for use in other disciplines. There are also strategies that are used to teach specific topics. They are "specific strategies that are useful for helping students comprehend specific" concepts within the content area (Magnusson, Krajcik, & Borko, 1999, p. 111). Two categories of topic-specific strategies are representations and activities. With this information, I reorganized the model cases to include the content- and topic-specific categories.

An Elaborated Model

After completing a revision of the section on model cases (see Appendex E), my advisor and I met for several hours to discuss how the constructs could be clarified even further. First, after reviewing the model cases for TCK, we decided not to include the cases for teacher knowledge of how technology can generate new content and how content can transform technology. Very few cases of these types of TCK were found in the literature or online. We agreed that, while these types of TCK are valuable, the lack of examples in the literature indicated that they may not be immediately useful to a classroom teacher. Additionally, they did not seem to help in clarifying the distinctions between the constructs.

The issue of pedagogical strategies continued to be of concern, particularly because many of the topic-specific examples often seemed to implement fairly generic instructional strategies but used a specific representation of content. I felt that this concept could be better represented. In re-reading the chapter on PCK by Magnusson, Krajcik, and Borko, I noticed that they had separated knowledge of topic-specific instructional strategies into two categories: knowledge of topic-specific representations and knowledge of topic-specific activities. As my advisor and I reflected on these categories, we realized that they provided an excellent framework for illustrating the distinctions between each of the TPACK constructs.

We considered that each of the constructs was in some way composed of activities, representations, or both. Examining the model cases supported this idea. The TPK construct represents a teacher's knowledge of activities with technology. TCK represents a teacher's knowledge of topic-specific representations with technology. TPACK brings both components together, representing a teacher's knowledge of content-specific activities and topic-specific representations. The activities in TPACK can be further deconstructed into subject-specific activities and topic-specific activities. The question remained as to whether general activities, such as those found in TPK, are also part of the TPACK construct when combined with topic-specific representations. I determined that the use of a general activity with a topic-specific representation to teach a particular concept actually concurred with the definition Magnusson, Krajcik, and Borko (1999) had provided for topic-specific activities.

Crafting the Graphic Organizer and Final Discussion

After creating this elaborated model of the TPACK framework, I worked to refine and exemplify it. I first created the graphic organizer to better visualize the model. I chose to modify the original Venn diagram created by Mishra and Koehler rather than create a completely new graphic in order to facilitate discussion among TPACK scholars about the elaborated framework. Additionally, the diagram helps to demonstrate the intersections of and boundaries between each of the domains in the framework. A Venn diagram is used in categorical logic as a tool to assist one's thinking about relationships between given classes (R. Sudweeks, personal communication, July 2, 2008). In the case of this graphic organizer, the Venn diagram allowed me to demonstrate the relationships and boundaries between each of the constructs.

With that graphic representation, I was able to select cases—both real and invented—that exemplified the constructs and prompted discussion about the boundaries between them. Thus, the final discussion in this dissertation does not represent the step-by-step process outlined earlier in this chapter. Rather, it demonstrates my final understanding of the TPACK framework and the questions that are, as yet, still unanswered.

CHAPTER 4: PRELIMINARY RESULTS

Before I could clarify the definitions and boundaries of the TPACK framework, I needed to ensure that I fully understood it. The preliminary results described here detail the definitions and essential features of the constructs in the TPACK framework as they have been illuminated by those who have already published work in this area.

Technical Use Analysis

The purpose of the technical use analysis was to help me better understand how other researchers had defined and utilized TPACK in the literature. This analysis revealed the complexity of the framework as well as the variability with which it has been used. The following sections discuss the definitions and examples of TCK, TPK, and TPACK as found in the literature.

Technological Content Knowledge (TCK)

I noted 13 definitions of TCK in the selected resources (see Appendix B). As defined by Koehler and Mishra, TCK is an "understanding of the *impact* of *technology* on the practices and knowledge of a given *discipline* (2008, p. 16, italics added). Indeed, all but one of the definitions cited here include the concepts of *technology* and *content* and some form of relationship between them. This interaction is expressed in a number of ways including *impact* (Koehler & Mishra, 2008, p. 16), *influence and constrain* (Koehler & Mishra, 2008, p. 16), *dictate or change* (Koehler & MIshra, 2008, p. 16), *represent* (Koehler & Mishra, 2008, p. 21), *reconceptualize* (Hughes & Scharber, 2008, p. 102), *interconnect* (van Olphen, 2008, p. 113), *reciprocal relationship* (Mishra & Koehler, 2006, p. 1028), *change* (Mishra & Koehler, 2006, p. 1028), *transform* (Koehler & Mishra, 2005a, p. 134), *afford and constrain* (Mishra & Koehler, 2007, p.

2220), *limit* (Mishra & Koehler, 2007, p. 2220), *format* (Archambault, 2008, p. 5192), and *interact* (Robertson, 2008, p. 2219).

Thus, it appears that TCK can be conceptualized as an understanding of the relationship between technology and content. In particular, that relationship seems to manifest itself in the representation of content through technology. However, Koehler and Mishra as well as Archambault add another dimension to TCK which may be the source of some of the confusion surrounding this construct. In two of their definitions, Koehler and Mishra mention teaching or learning and Archambault mentions students. These words seem to imply that, though pedagogy is theoretically not present in this construct, the classroom context is. Meanwhile, Robertson (2008) argues that TCK cannot exist in a classroom context as that context necessarily injects pedagogical considerations. This is one of the major issues that must be addressed by TPACK experts. At this point in the conceptual analysis, pedagogical context will not be listed as an essential feature of the TCK construct.

Further features of TCK were also found in the literature. TCK is not just an understanding of how technology can be used to represent content, but also an understanding of how technology can change or even generate content. It is a realization of how particular technologies might open up "new fields of content that had not been previously illuminated and clearly understood" (M. Niess, personal communication, April 28, 2008). This aspect of TCK is alluded to in definitions and occasionally highlighted with examples (e.g., Carbon-14 dating (Koehler & Mishra, 2008)), but there is little, if anything, about what that would look like on a daily basis, particularly in an educational setting.

One definition of TCK takes a very different stance on the TCK construct. Hughes (2008, p. 5229) states that TCK is an understanding of "technologies that could be considered *new* *content* in their disciplines." This statement seems to imply that TCK is, or at least involves, the acceptance of technology as a new area of study in a given content area – the teaching of appropriate technologies to students. There are few references in the TPACK literature to the teaching of technology to students. Most focus on the use of technology to teach content. However, this is a very important concept to consider in the attempt to clarify and define the constructs because students must learn how to use the technology, particularly technologies that are specific to a given content, in order to successfully implement it.

With the inclusion of this facet of TCK, an expansive definition of this construct based on the technical use analysis may be: an understanding of the technologies that may be utilized in a given discipline and how the use of those technologies transforms the content of that discipline through representation or the generation of new content. Examples of the construct from the same literature help to further define the construct. The examples that I utilized in the technical use analysis were specifically labeled in the literature as representing TCK.

The confusion surrounding the TCK construct is more evident in the examples provided in the literature (see Appendix C). These examples vary from lists of technologies that might be used with a given content to detailed examples of how a teacher might use a given technology in the classroom. For example, Hughes and Scharber (2008) provide the following example of TCK: "Inspiration, StorySpace, HyperStudio, ClarisWorks, a web-based asynchronous communication tool, and the Internet were used during the project" (p. 92). Meanwhile, Koehler and Mishra (2006) describe the following scenario as exemplifying TCK:

> Consider Geometer's Sketchpad as a tool for teaching geometry. It allows students to play with shapes and form, making it easier to construct standard geometry proofs. In this regard, the software program merely emulates what was done earlier when learning geometry. However, the computer program does more than that. By allowing students to 'play' with geometrical constructions, it also changes the nature of learning geometry

> itself; proofs by construction are a form of representation in mathematics that was not available prior to this technology. Similar arguments can be made for a range of other software products. (p. 1028)

Koehler and Mishra's Geometer's Sketchpad example is particularly confusing because it refers to software that was created for use in a pedagogical context. Sketchpad is not a tool that mathematicians use, but rather a tool for teaching mathematics. Thus, a teacher's knowledge of how to use Sketchpad to represent mathematical concepts is almost certainly connected to his knowledge of pedagogy, blurring the line between TCK and TPACK.

Throughout this conceptual analysis, I focused on clarifying this construct through discussion with TPACK experts and classifying examples based on the essential features of the construct. After a review of the literature, the essential features of TCK are (a) the use of technology (b) in a particular content area (c) to change the representation of that content. Issues of concern with regard to TCK are (a) whether a pedagogical context is appropriate when considering TCK and, if so, where the boundary between TCK and TPACK is; (b) whether listing technologies used in a particular content area constitutes a level of TCK; and (c) whether or not TCK can, in fact, exist in an educational context.

Technological Pedagogical Knowledge (TPK)

In order to discover how TPK was defined in literature, I located 10 definitions of TPK in the selected resources (see Appendix B). Koehler and Mishra (2008) defined this construct as "an understanding of how teaching and learning changes when particular technologies are used" (p. 16). After a review of the TPK definitions, components of the construct were revealed in more detail. First, TPK requires an understanding of the technological tools available for teaching and the affordances and constraints of each. Inherent in this knowledge is an understanding that technology can also be misused and that each technology has limitations.

Second, TPK includes knowing how to use those tools in an educational context, often by repurposing a tool not originally intended for instruction. Third, one with TPK could also recognize how the use of that technology interacts with pedagogy by either changing or supporting the strategies that are used and, conversely, by noticing how the choice of a particular pedagogical strategy will influence the choice of technology.

Hughes (2008) emphasizes that TPK refers to the use of technology "as a *general* pedagogical tool" (p. 5229, emphasis added). However, Koehler and Mishra repeatedly refer to the role of "disciplinary contexts" in TPK (Koehler & Mishra, 2008, p. 17; Mishra & Koehler, 2007, p. 2220). This reference to content highlights what is perhaps the greatest debate surrounding the TPACK framework – namely, is it possible for teachers to possess and/or demonstrate knowledge of the interaction of technology and pedagogy without considering content? This is another major issue that must be addressed with the TPACK experts.

For the purpose of creating an expansive definition of this construct which will facilitate classification of examples, I posit that reference to a particular content is not an essential feature of the TPK construct. Thus, the expansive definition presented here is that TPK is an understanding of the technologies that may be used in a given pedagogical context, including the affordances and constraints of those technologies, and how those technologies influence or are influenced by the teacher's pedagogical strategies. Examples from the literature illuminate the features of this construct.

Again, the confusion surrounding this construct is evident in the examples provided in the literature (see Appendix C). With this construct, the questions lie in whether or not content can play a role in TPK. Additionally, it is extremely difficult to draw the line between TPK and TPACK in that both are used in an educational context and it seems to be a matter of how much detail is provided regarding that context to classify the example as belonging to one or the other. Examples of TPK range from lists of technologies that teachers can use for instruction and classroom management to best practices for using particular technologies in the classroom and technology integration scenarios. Some of the questions this study attempts to answer are

1. What makes those scenarios demonstrative of TPK rather than TPACK?
2. Is it the level of detail?
3. If so, what is the right level of detail for each construct?

Another question that arose between myself and my committee chair pertains to which instructional strategies are being implemented. Does TPK refer to the use of general pedagogical strategies (e.g., collaborative learning, problem-based learning, etc.) with technology rather than content-specific pedagogical strategies (e.g., primary source research [social science], inquiry-based learning [science], etc.) that use technology? Or is the distinction less clear than this?

Based on the definitions and examples provided in the resources investigated here, I propose that the essential features of TPK are (a) the use of technology (b) as part of a pedagogical strategy (c) and how the technology and pedagogy interact. The questions remaining after the technical use analysis that needed to be posed to the TPACK experts include (a) whether content can/should play a role in TPK; (b) how one can distinguish between TPK and TPACK, particularly because teachers do not often separate teaching from content; and (c) whether the nature of the instructional strategy plays a role in TPK/TPACK classification.

Technological Pedagogical Content Knowledge (TPACK)

The most succinct definition of TPACK I have found to date is this: TPACK is knowledge of “how to use technology to help students learn a particular topic” (Koehler & Mishra, 2008, p. 21). But as further examination of 89 definitions from the selected resources (see Appendix B) demonstrated, that definition is perhaps too simplistic to represent the complexity of this construct. This oversimplification of the construct in the literature has, in Leatham's words, "hamper[ed] the usefulness of the TPCK framework" (2008, p. 5281). The true outcome of TPACK, according to researchers, is the ability to "develop meaningful learning experiences for students that integrate technology use effectively" (AACTE, 2008, p. 293) or "good teaching with technology" (Koehler & Mishra, 2008, p. 11) or "effective teaching with technology" (Koehler & Mishra, 2008, p. 12). These statements suggest a much richer definition of the construct than the one above, implying a level of quality in the technology use. Thus it is important to consider the essential features of TPACK to determine how that quality is achieved.

Inherent in the TPACK acronym is the idea that this construct is composed of three distinct knowledge domains—technology, pedagogy, and content. I discovered 89 definitions of TPACK in the literature selected for this review (see Appendix B) that illuminate further features of the construct. The first, and most often mentioned, characteristic of TPACK is the complexity of the construct.

The Complexity of TPACK

Researchers have repeatedly emphasized that TPACK is not a simple construct and that the relationships between the knowledge types is equally intricate. The complexity of this relationship has been described in the literature with terms such as dynamic, transactional, mutually reinforcing, synergistic, and interdependent. McCormick and Thomann illustrate the give-and-take in this relationship by describing TPACK as "the integration of choosing *the appropriate pedagogy for teaching content and technology* and *the appropriate technology for the content*" (2007, p. 2204, emphasis added). Thus it is apparent that, in order for one to possess

TPACK, one must first possess each of the knowledge types and second understand the intricacy of the relationship between those domains.

Also contributing to the complexity of the construct is the nature of the knowledge involved. Technological knowledge, pedagogical knowledge, and content knowledge are each very dense and multifaceted domains. New skills and understandings emerge when these domains are combined. Koehler and Mishra describe the understandings required for TPACK as "(a) the representation of concepts using technologies; (b) pedagogical techniques that use technologies in constructive ways to teach content; (c) knowledge of what makes concepts difficult or easy to learn and (d) how technology can help redress some of the problems that students face; (e) knowledge of students' prior knowledge and theories of epistemology; and (f) knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones" (Koehler & Mishra, 2008, p. 17-18; Mishra & Koehler, 2006, p. 1028-1029; Mishra & Koehler, 2007, p. 2221, seriation added).

Alternatively, Niess uses the framework for PCK provided by Grossman (1991) to describe the four central components of TPACK as (a) an overarching conception about the purposes for incorporating technology in teaching [a given content]; (b) knowledge of students' understandings, thinking, and learning in [a given content] with technology; (c) knowledge of curriculum and curricular materials that integrate technology in learning and teaching [a given content]; and (d) knowledge of instructional strategies and representation for teaching and learning [a given content] with technologies (Niess, 2008, p. 5298; Niess, 2005, p. 511). Thus, while researchers can agree that TPACK is complex, it is not yet clear what exactly that complexity entails.

A third problem that contributes to the complexity of the construct and perhaps adds to the confusion in classifying examples as belonging to one or another of TCK, TPK, or TPACK, is that all of these constructs are overlapping. An examination of the TPACK diagram by Koehler and Mishra reveals that, while TCK lies at the intersection of technology and content, TPACK is actually a *subset* of that knowledge. It is also a *subset* of the intersection of technology and pedagogy (TPK) and a *subset* of the intersection of pedagogy and content (PCK). Thus, all TPACK, according to this diagram, is also TCK, TPK, and PCK (see Figure 4.1).

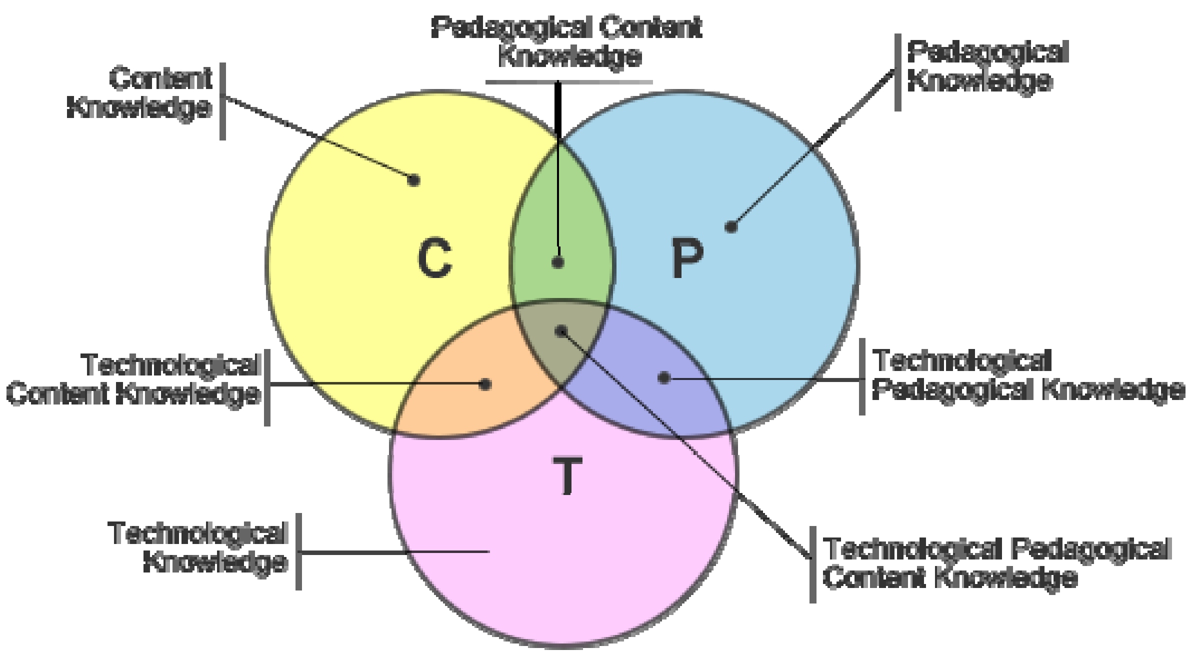

Figure 4.1. The original TPACK diagram by Koehler and Mishra (image source: http://www.tpck.org).

Trautmann and MaKinster (2008) allude to this intricate relationship when they state that “the size of this overlap [the center of the TPACK diagram] indicates the extent to which a teacher has developed an integrated understanding of the complex relationships between subject matter understanding, pedagogical goals, and available technologies" (p. 4792). Therefore, as a person's TPACK grows, there is *less* TCK as an independent construct and *less* TPK as an independent construct. This, perhaps in part, answers Hughes question regarding the existence of TCK in educational contexts. Because teachers already assumedly possess PCK, TCK in those same teachers may look very like TPACK. Additionally, this diagram suggests some conceptual overlap among the three constructs which has not been fully explored. Whereas the purpose of this dissertation is to better understand how to discern between TCK, TPK, and TPACK, I will attempt to illuminate the distinctions between these constructs. However, it is important to recognize where and how they overlap, particularly as it adds to the complexity of the framework.

Further Features of TPACK

In addition to the complexity of TPACK, the technical use analysis revealed several additional features of this construct as described in the following sections.

Context. A second feature of TPACK, and one that is currently enjoying much attention in the research, is context. One reason why TPACK (and PCK before it) has proven so difficult measure is that the knowledge must be exhibited in some context. Therefore, TPACK (and PCK) look slightly different in each instance. Included in the idea of context are such things as the school environment, the physical features of the classroom, the availability of technology, the demographic characteristics of students and teachers including prior experience with technology, the particular topic being taught, the preferred instructional methods of the teacher, etc. (Kelly, 2008). The effect of context is that TPACK is unique, temporary, situated, idiosyncratic, adaptive, and specific and will be different for each teacher in each situation. As Koehler and

Mishra described it, "There is no single technological solution that applies for every teacher, every course, or every view of teaching" (2006, p. 1029). Thus, any true example of TPACK must necessarily include the context of that example. Koehler and Mishra have acknowledged the importance of context in the TPACK framework by adapting the visual model to include context as a major feature as shown in Figure 4.2.

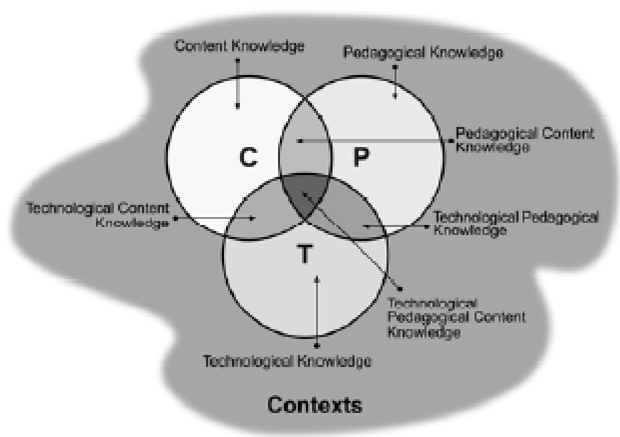

Figure 4.2. The revised model of TPACK as seen in Koehler & Mishra, 2008, p. 12.

Knowledge. Another aspect of the construct that makes it difficult to measure is that TPACK is, in reality, a "way of thinking" (Niess, 2008, p. 5297; Niess, 2008, p. 224), an "intuitive understanding" (Schmidt, Seymour, Sahin, & Thompson, 2008, p. 5314) or, as van Olphen describes it, "a matter of thinking imaginatively about 'how' technology may support teaching and learning" (2008, p. 118). More simply stated, TPACK is a form of *knowledge*. Therefore, in order to measure TPACK one would have to measure what teachers are thinking as they plan, organize, critique, and abstract for the context (Niess, 2008, p. 224). It would seem that a model case of TPACK must include a description of why the teacher created the learning environment described. However, most published examples of technology integration provide description of the actual implementation rather than the reasoning behind that implementation, making it difficult to find a model case that would include this feature.

Access. Kelly argues that another feature of TPACK involves a teacher's "knowledge and skills in identifying and appropriately responding to differential levels of access to technology among students" (2007, p. 2200). Perhaps the issue of access could be included with demographic issues under context, but it may be wise to further consider this issue as recent research demonstrates that access to technology may contribute to a widening of both educational and economic gaps between the poor and the wealthy (Lucas & Sylla, 2003; Williams, Carr, & Clifton, 2006). With the global perspective of the twenty-first century, teachers with TPACK should consider issues concerning access to technology such as determining levels of access among one's students, local resources for access, and differentiation. However, for the purposes of this study, as this is a very new inclusion in the TPACK debate, access will not be an essential feature for a model case of TPACK.

Levels. Some researchers have also acknowledged that teachers can possess different levels of TPACK and that TPACK development is a process (for example, Kelly, 2008; Kelly, 2007; Niess, 2008; Niess, 2006). Therefore, when examining TPACK, one must also consider that different teachers may demonstrate differing levels of TPACK. While a teacher with strong TPACK may exhibit certain characteristics, a teacher with weak TPACK may exhibit very different ones, further convoluting the study of the construct. While Niess (2008) goes into great detail describing different possible levels of TPACK, others are satisfied to suggest that there might be "strong" or "weak" TPACK. The decision must be made as to whether or not the level of TPACK is a consideration when classifying examples as TPACK.

In addition to the idea of levels, Robertson argues that the implementation of TPACK actually occurs in a series of steps (2008). She posits that a teacher begins with the content, then considers the context. Next, pedagogical content knowledge is used to determine which content to teach in the particular context. Fourth, technology can be considered, followed by technological pedagogy as the teacher decides how the technology will fit into the pedagogy being used. Finally, "the instructor must relate Technological Pedagogy with the particular content at hand" (Robertson, 2008, p. 2219). Though this theoretical model has not yet been tested, it is an interesting illustration of the possible progression of TPACK on a daily basis in a classroom setting. These theories of levels and steps in TPACK are as yet unproven but provide points of discussion for TPACK researchers.

Perspective. Bull et al. (2007) illustrate another difficulty in measuring or exemplifying TPACK when they state that TPACK can be examined from at least three different perspectives. "For instance, one could focus on Pedagogy and see how it interacts with Technology and Content. Alternatively, one could focus on one content area, and see how Pedagogy and Technology can be best utilized to develop student understanding of core content ideas" (p. 131). A third possibility is "considering the affordances (and constraints) imposed by one particular technology and its interaction with content areas and pedagogical goals" (Bull et al., 2007, p. 131). This statement implies that TPACK may look different depending on the perspective from which one is examining it. However, it also indicates the breadth of research possibilities that are suggested by this construct, demonstrating the value of the framework.

The expansive definition presented here is that technological pedagogical content knowledge is a way of thinking about the complex relationships between technology, pedagogy, and content in a specific context which is represented through the carefully considered implementation of technology in a classroom setting in order to help students better understand a particular topic.

Examples of TPACK

As with the definitions, there are many more examples of TPACK than of the other constructs. Additionally, these examples are longer and more detailed because, as was stated earlier, an example of TPACK generally also contains an explanation of the context in which it took place. Some of these examples are real and other are invented by the authors, but an examination of all of the examples should provide a more solid foundation for defining the construct.

The most noticeable attribute of these examples (see Appendix C) is that nearly all illustrate a unique context in which the teacher used (or considered the use of) technology to enhance students learning of a particular topic. The examples are very context-dependent, meaning that the solutions chosen in these scenarios may not be appropriate for every topic, every group of students, or every teaching-learning situation. Also, the technology is being used for a particular purpose, not just for the sake of using technology. However, a degree of complexity is added to the examples as some represent different levels of TPACK, which may make it more difficult to classify examples as representing the TPACK construct.

In looking for examples of TPACK, the essential features must be (a) the use of technology (b) in a particular educational context (c) to teach a particular content (d) to fulfill a given educational objective/student need. Questions remaining for the TPACK experts are

1. Must TPACK include the use of content-specific pedagogical strategies rather than generic ones (see the technical use analysis of TPK)?

2. How much detail must be provided regarding the context in order to classify an example as TPACK (versus TCK or TPK)?

3. How to address the idea of levels in searching for examples of TPACK.

Results and Discussion of Interviews

Upon completing the technical use analysis, I conducted interviews with seven individuals who are active in TPACK research. The individuals that I interviewed were

1. Punya Mishra: one of the originators of the TPACK framework and an educational technology professor with a varied scholarly background including electrical engineering, visual communication, and technology integration.

2. Matthew J. Koehler: one of the originators of the TPACK framework and an educational technology professor with a background in computer science, mathematics, and cognitive psychology.

3. Keith Leatham: a former high school mathematics teacher and current mathematics education professor who presented on the components of TPACK at the 2008 International Conference of the Society for Information Technology & Teacher Education.

4. John K. Lee: a former middle school social studies teacher and current social studies and middle grades education professor who wrote a chapter on TPACK in the social studies in the 2008 *Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators*.

5. Neal Grandgenett: a former middle school mathematics teacher and current mathematics education professor who wrote a chapter on TPACK in mathematics in the 2008 *Handbook*.

6. Maggie Niess: a former middle school, high school, and college mathematics teacher and emeritus mathematics education professor who has published extensively on TPACK and wrote a chapter on developing TPACK in the 2008 *Handbook*.

7: Anonymous: One participant wished to remain anonymous. This person specializes in language arts education.

These individuals were presented with a summary of the technical use analysis including the definitions, essential features, and remaining questions for each construct (see Appendix D). The nature of the instructional strategies used in TPK and TPACK was a concept of particular interest in those remaining questions.

Each interviewee was asked the same core questions as well as some customized questions based on that person's publications (see Appendix A). The core questions involved reviewing the definitions and essential features derived from the technical use analysis and questions related to the remaining questions for each construct. Participants were also asked to describe model cases for each of the constructs. The interviews resulted in revision of the definitions and essential features for each construct as well as additional considerations about the TPACK framework.

The Overall TPACK Framework

The interviews resulted in answers to questions about not only the individual constructs but also about the TPACK framework as a whole. The following sections describe the conclusions about the framework that resulted from the interviews.

A Framework of Teacher Knowledge

One of the primary questions regarding the TPACK framework was whether each construct represented a unique aspect of teacher knowledge or if some types might only be found outside of the educational context. This question was particularly apparent in the TCK literature as some argued that teachers could not possess TCK without infusing some pedagogy into it. In our interview, Koehler emphasized that TPACK is a framework of teacher knowledge and that teachers can possess each distinct type of knowledge within the framework. Of course, others can also possess some of the types of knowledge within the framework. For instance, a physicist may have technology knowledge as well as content knowledge as well as technological content knowledge, but that physicist would not have pedagogical knowledge or any of its overlapping spheres of knowledge (PCK, TPK, or TPACK). The inquiry here will focus on teacher knowledge within these constructs.

An Emphasis on Knowledge

A second theme that was prevalent in the interviews was that TPACK is a framework for *knowledge*. A vast majority of the examples currently found in TPACK literature are, in fact, activities. But how much do these activities truly reveal about the teacher's knowledge? Two interviewees were particularly adamant about the need to focus on the knowledge that a teacher has in this framework. Leatham argued this point most ardently in his interview, enumerating several questions that must be asked of teachers in order to better understand their knowledge as evidenced by a particular activity. Leatham states that one would have to ask questions such as,

> 'What were you thinking? What were you doing? Why did you choose to do that?' to get at were they really thinking about content when they were doing this or was it really more of a generic pedagogical decision. You'd have to ask those kinds of questions in order to determine it. So I think that many of the scenarios that you've found in the literature, it's impossible to tell from the information they've given because they haven't really thought about the knowledge the person had when they did those things." (Interview)

Thus, the search for cases in this conceptual analysis is, in fact, a search for evidence from which a teacher's knowledge and intent will be inferred.

The Purpose of the TPACK Framework

Another major question that arose from the literature review for this dissertation centered on the need for the TPACK framework. In Shulman's original descriptions of PCK, he mentions technology several times, particularly as a component of curriculum knowledge or knowledge of the tools available to teach content. This begs the question of the purpose of the TPACK framework. Both in the literature (Hughes & Scharber, 2008; Grandgenett, 2008) and in the interviews, it was emphasized that TPACK serves to focus the discussion in education on a more connected view of technology. As expressed by Niess, "when you don't overtly talk about it by putting it right in front of people's faces, they tend to not talk about it and not think about the integration" (interview). However, everyone interviewed agrees that the need for the TPACK framework may be temporary, that once educational technology is given the same level of consideration as content and pedagogy and when teachers have come to understand the complexities of technology use in the classroom, there will no longer be a need for the separate framework. For now, the high-profile framework helps to begin and focus the discussion on technology in the classroom.

Some Difficulties in Studying the TPACK Framework

A major hurdle in this search for cases will be the level of detail provided in most published examples. The interviews revealed a perception that the classification of an example as exhibiting TCK, TPK, or TPACK may often come down to the amount of detail in that example. If questions such as those suggested by Leatham are not asked and answered in the examples, understanding the teacher's intent for the activity will be extremely difficult. Grandgenett believes that, to some extent, this difficulty will be alleviated by the use of the essential features to classify examples of each construct. However, Niess and others argued that detail will be a major obstacle as most published examples do not discuss the purpose behind the technology use, and we currently have very few examples of what TPACK looks like. A lack of detailed examples means that determining the definition and essential features of TPACK will be difficult.

Additionally, because TPACK is a very complex and dynamic form of knowledge, no one ever fully *possesses* it. Technologies and content areas are constantly changing; and there are innumerable variables in every classroom context, meaning that a person's TPACK is in a constant state of flux. Thus far, the TPACK field is still quite young and the constructs are not very clear. Therefore, not only is TPACK quite possibly limitless (Grandgenett, 2008), but there is, as yet, little understanding of what it actually is and, more specifically, what it looks like. For that reason, several of the interview participants were reluctant to endorse the pursuit of quantitative measures in this area as they felt that it is extremely difficult to measure something that is not fully understood. Koehler, though currently working on a quantitative measure, is not yet sure that the construct can be measured in this way, However, he also stated that, if the survey instrument is valid and "it comes down to there are really only two things, we should stop talking about the seven things on our picture" (M. Koehler, personal communication, May 2, 2008).

Some interviewees also suggested postponing the investigation of levels in the TPACK framework for the same reason. Several respondents suggested that it is simply too early in the study of the framework to make judgments about what is strong or weak knowledge in this area. Additionally, Leatham argued that there may be multiple reasons why a person's knowledge is perceived as weak, stemming from weakness in any of the types of knowledge contributing to TPACK. Many called for more solid examples with rich, thick description before judgments can be made. Mishra and Koehler agreed that, while relative judgments may be possible (for example, this is a better use of technology than that), no one can make absolute judgments about what is best or right because every situation is different. However, Niess maintains that the discussion of levels helps professional developers and teacher educators to realize that developing TPACK is an iterative process and that each individual's knowledge will develop differently.

One contributor to the general confusion surrounding the TPACK framework seems to be the issue of perspective. The interviews revealed that some of those who are teacher educators tended to think of TPACK largely in terms of how it is developed in their students, resulting in examples that focused on preservice and inservice teachers' acquisition of TPACK, rather than recognizing it as it already exists in practicing teachers. Thus, their conception of TPACK is wrapped up in how teacher candidates attain it rather than how it might be manifested in a classroom setting. For example, Leatham, Niess, Grandgenett, and others spent much of the time in their interviews discussing how the preservice teachers they work with gain TPACK. Mishra and Koehler focused on things they do in their classes that exhibit TPACK. Lee was the only interviewee whose responses focused almost entirely on the classroom teacher's knowledge and skills. Additionally, those who are generalists seemed to more easily perceive the feasibility of TCK, TPK, and TPACK as three distinct constructs whereas those who are content area experts seemed to have more difficulty separating the constructs, particularly TPK. The purpose of this dissertation is to focus on what this knowledge might look like in practice rather than to determine how it is acquired or developed.

Lee and Mishra also emphasized the need for a broad definition of technology in any investigation of TPACK. As Lee describes it, "technology has deeply impacted education from the beginning in a lot of ways" (J. Lee, personal communication, May 5, 2008). Therefore, the search for examples should not be limited to computer technologies but should also include what Mishra refers to as "transparent" technologies—those that have been used in the classroom for so long that they are no longer referred to as technologies, namely, the pencil, the whiteboard, and the face-to-face classroom, among others (P. Mishra, personal communication, May 2, 2008). They feel that observing how teachers use these technologies as well as or compared with computer technologies will help to illuminate TPACK.

Technological Content Knowledge (TCK)

TCK is a tricky construct in that some researchers are not convinced that it can exist in the mind of someone whose primary focus is teaching. Mishra admitted that they have been "a little muddled about it" as they have thought and written about the construct because pedagogy cannot play a role in this form of knowledge. However, Koehler emphasized that the framework was intended to represent teacher knowledge. Thus, the line between TCK and TPACK is the introduction of knowledge about teaching and learning, which is a very easy line for teachers to cross.

All of the interviewees agreed that it was possible for a teacher to have pure TCK without injecting pedagogy, but with various caveats and qualifiers. Everyone perceived that there were definitely technologies that were specific to different disciplines. Additionally, Koehler emphasized that if a teacher can have pure knowledge about a given content area they "could have pure knowledge about what technology does for" that content area. Some, Niess among them, suggested that TCK will be most pure in preservice teachers who have not yet thought much about pedagogy. Lee felt that practicing teachers would only pursue TCK if they have a particular interest that drives them to do so. This corresponds with Grandgenett's response that

TCK may be more prevalent in content-specific teachers, perhaps correlating with the grade-level in which that teacher provides instruction. Several agreed with the idea that while a college professor would have strong TCK an elementary teacher probably would not.

Evidence for this argument was found in two additional interviews, one with a university geology professor and the other with a fifth grade teacher. The university professor had extensive TCK, elaborating on her use of particular tools and technologies that helped her learn more about geology and that, in turn, had changed the field of geology. However, when the fifth grade teacher was asked to identify specific software or tools for math or science, he could not name anything more specific than a couple of websites and the lessons that came with his interactive whiteboard. These examples suggest that the existence of TCK in teachers of different grade levels and subject areas may be a rich topic for future investigation.

The TPACK experts who were interviewed also emphasized that listing websites or software in a given content area does not constitute TCK. Rather, the teacher must not only be aware of the technology but must also know how to use it (TK) and must understand the purpose for doing so in the context of the discipline. As Mishra stated, “any kind of technology comes with a bunch of possibilities and potential,” and a teacher with TCK would understand the possibilities and potential of a given technology in his particular content area. Leatham emphasized that a teacher with TCK would know how to use a program or tool to *do* her discipline. Thus, it is not sufficient to simply list technologies or even to know how to use the technologies (TK), but the teacher must also understand the implications of that technology for his content area.

The interviewees also recommended changes to the definition and essential features for TCK. The original definition and essential features were

> Definition: An understanding of the technologies that may be utilized in a given discipline and how the use of those technologies transforms the content of that discipline through representation or the generation of new content.
>
> Essential Features: (a) the use of technology (b) in a particular content area (c) to change the representation of that content

Koehler and Mishra felt that the definition and essential features provided one of the best explanations they had seen of half of the construct, but that it did not fully represent the bidirectional relationship that exists between technology and content. Koehler stated that the definition did not express “how content would transform or constrain or afford technology.”

Grandgenett and Leatham both felt that the third essential feature was confusing and should be reworded to emphasize that the relationship between technology and content is about more than representation. Niess further recommended that the word “appropriate” be used to enhance the idea that certain technologies are more beneficial in certain content areas. Finally, some worried that the word “understanding” did not mean the same thing as “knowledge” and that, because the construct represents a type of knowledge, the wording should be more precise.

Based on these suggestions, the new expansive definition for TCK is a knowledge of appropriate technologies that may be utilized in a given discipline and how the use of those technologies transforms the content of that discipline through representation or the generation of new content or how the content of that discipline transforms or influences technology. The essential features of TCK are (a) the use of appropriate technology (b) in a particular content area (c) to investigate, represent, or transform that content *or* (a) the selection or transformation of technology (b) based on the imperatives of a particular content. These essential features form the foundation for classifying examples of teacher knowledge that might typify this construct.

Technological Pedagogical Knowledge (TPK)

As a generalist, I assumed that TPK would be a well-accepted construct. However, the interviews revealed a great deal of confusion and doubt surrounding TPK. Everyone did agree that TPK had to be neutral with respect to content, meaning that it had to involve thinking about technology and teaching without referring to a specific discipline. Everyone also agreed that TPK would only include generic pedagogical strategies because using content-specific strategies would necessarily include a particular content. The participants did not, however, agree on what exactly TPK is or whether a teacher could have pure TPK without injecting content.

Several interview participants suggested that it would be difficult for a teacher to have pure TPK. Those who were subject matter specialists, such as Leatham and Lee, stated that having a knowledge of how to use technology in teaching without talking about content would be less valuable for teachers than consideration of technology in the context of a given discipline. For others, the sentiment that most teachers wouldn't have TPK may have arisen from an apparent misunderstanding of the meaning of the construct itself. Two of the experts who were interviewed were under the impression that TPK referred to a knowledge of how to teach technology to students rather than a knowledge of how to teach *with* technology. One referred to TPK as "technology knowledge and then however you teach that in a pedagogical kind of way" while another said, "It's the way that the technology teacher in the school thinks about pedagogy." But Niess emphasized that TPK is about students learning with the technologies, not about them. Additionally, Koehler underlined that the TPACK framework is not about what students know, but what teachers know. Therefore, TPK is a teacher's knowledge of how to use technology in their teaching, not how to teach technology. This is supported by Mishra and Koehler's (2006) definition of TPK which emphasizes that the construct refers to the use of technology to support teaching. Lee suggests that knowledge of how to teach technology to students is, in fact, PCK with technology as the content.

This seems more in keeping with the intent of the framework as a teacher could use technology in various ways to teach students how to use technology (TPACK). One example of this is a program called Alice which is used in several universities, colleges, and high schools to teach students how to do computer programming. In this case, computer technologies are used as a pedagogical tool to allow "students to learn basic computer science while creating animated movies and simple video games" (Pausch, nd, p. 1). A teacher who knows how to use Alice to teach students how to program would have TPACK as opposed to just TPK.

The interviewees also emphasized some interesting facets of TPK that are not often discussed in the literature. First, Lee mentioned that a large part of TPK is the teacher's disposition toward technology in the classroom. A teacher with strong TPK would have an open and accepting disposition toward the use of technology. Second, Mishra accentuated the idea that the use of certain technologies in one setting may change a teacher's instructional strategies in another circumstance. For example, a teacher's instruction in a face-to-face class may change as a result of his experience with an online course. The long-term impact of the technology-pedagogy relationship is not often discussed in the literature. Finally, Leatham envisioned a strong and more useful form of TPK in which the teacher abstracts from their TPACK to devise universal principals for technology in the classroom. The literature more often refers to the development of TPACK after a teacher already has some TPK, so exploring the reverse may be an interesting avenue for research.

All of the interview participants agreed with the definition and essential features derived from the technical use analysis, which were

> Definition: an understanding of the technologies that may be used in a given pedagogical context, including the affordances and constraints of those technologies, and how those technologies influence or are influenced by the teacher's pedagogical strategies.
>
> Essential Features: (a) the use of technology (b) as part of a pedagogical strategy (c) and how the technology and pedagogy interact

Leatham commented that in the essential features, "part three really captures it. I mean, it's how technology and pedagogy interact. For me, I mean, that's really the essence of it." However, Niess did feel strongly that the term *pedagogical strategies* didn't fully capture the teaching and learning that should happen in a classroom where the teacher has strong TPK. She asserted that it would be important to emphasize that teachers with TPK also consider the student thinking that takes place when a particular technology is used or how students learn with technology. Therefore, the revised expansive definition is a knowledge of the technologies that may be used in a generic pedagogical context, including the affordances and constraints of those technologies, and how those technologies influence or are influenced by the teacher's pedagogical strategies and student learning. The essential features are (a) the use of appropriate technology (b) as part of a pedagogical strategy (c) considering the interaction of the technology and pedagogy (d) and student learning.

Technological Pedagogical Content Knowledge (TPACK)

The remaining questions surrounding TPACK after the technical use analysis were largely answered above in the section on the TPACK framework; namely, that the level of detail provided in examples may be a difficulty in classifying examples correctly and that most of the interviewees feel that the time is not yet right for a discussion of levels within the TPACK framework.

The final question surrounded the nature of the instructional strategies utilized by a teacher with TPACK. The interview participants were not in agreement on this issue. Many immediately said that a teacher with TPACK would utilize content-specific instructional strategies as opposed to the general pedagogical strategies found in an example of TPK. But Mishra warns of the "conflation of technology with constructivism," reminding researchers and teachers that "technology can be used for many different kinds of teaching" (P. Mishra, personal communication, May 2, 2008). Another participant responded that "sometimes the environments are just conducive to different methods of teaching and I think we need to respect that." Alternatively, other interviewees claimed that the inclusion of content in TPACK would require the use of content-specific instructional strategies. My opinion is that TPACK could include all kinds of teaching, both generic and specific, but that more research is needed in this area.

The interviewees had several suggestions to improve the definition and essential features of the TPACK construct. The original version resulting from the technical use analysis is

> Definition: a way of thinking about the complex relationships between technology, pedagogy, and content in a specific context which is represented through the carefully considered implementation of technology in a classroom setting in order to help students better understand a particular topic.
>
> Essential Features: (a) the use of technology (b) in a particular educational context (c) to teach a particular content (d) to fulfill a given educational objective/student need.

The most obvious of the recommendations was that pedagogy was missing from the essential features. Some researchers recommended using structures parallel to those used for the other constructs to ensure the inclusion of all facets of the construct and to emphasize similarities and differences between the constructs.

Another major recommendation was to remove the phrase "a way of thinking" from the definition as that implied a certain disposition or mindset toward technology use rather than a knowledge of something. Leatham also felt that the technology use does not necessarily have to be "carefully considered" as the definition suggests. Mishra suggested that the definition and essential features did not fully portray the "dynamic, transactional negotiation" that occurs when a teacher uses technology in the classroom. Lee also mentioned that the use of technology in the classroom often introduces an opportunity cost and Niess agreed that the definition needed to better represent the interrelationship between the various elements of TPACK.

Niess again recommended the accentuation of student thinking and learning as a fundamental consideration of a teacher with TPACK and argued for the use of the word "appropriate" in reference to the selected technologies. Finally, Grandgenett contended that a teacher with strong TPACK also exhibits an understanding of "the intent of the discipline or the process of the discipline" and how the content being taught fits into that intent or process, which is very similar to the original descriptions of Shulman's PCK. Therefore, the intent of the discipline will not be included in the definition and essential features because it is assumed to be part of PCK and I fear that very few examples will demonstrate this concept, rendering it useless as an essential feature for the construct.

Based on these recommendations, the revised expansive definition of TPACK is a knowledge of the dynamic, transactional negotiation among technology, pedagogy, and content and how that negotiation impacts student learning in a classroom context. The essential features are (a) the use of appropriate technology (b) in a particular content area (c) as part of a pedagogical strategy (d) within a given educational context (e) to develop students' knowledge of a particular topic or meet an educational objective or student need.

Precising Definitions

While the technical use analysis helped me to better understand the existing definitions and uses of the TPACK framework, I found that the expansive definitions were too broad to facilitate the classification of examples of teacher knowledge. Therefore, I crafted a set of precising definitions that emphasize the distinctions between the constructs.

The precising definition of TCK became a knowledge of the technology-content interaction independent of pedagogy. Based on the full definition of the construct after the revision of the technical use analysis, I focused on three major types of TCK, namely, knowledge of (a) how technology represents content, (b) how technology generates new content, and (c) how content transforms technology.

While the interviewees agreed with the proposed definition of TPK, it was very broad and didn't help to distinguish between examples of TPK and TPACK. Therefore, the precising definition of TPK became a knowledge of the technology-pedagogy interaction independent of topic-specific representations or content-specific instructional strategies. Generic instructional strategies that might be included in TPK are the use of technology to improve motivation, communication, visualization, and classroom management, among others.

A more precise version of the TPACK definition became a knowledge of the technology-pedagogy-content interaction in the context of content-specific instructional strategies. This definition acknowledges the presence and interaction of all three components with particular emphasis on the use of content-dependent pedagogy.

While these definitions seem to oversimplify the constructs, their purpose is solely to clarify the boundaries between them. The technical use analysis and interviews helped me to fully understand the complexity of each construct as is demonstrated in the more detailed definitions provided earlier. However, as the purpose of this study was to provide clearer descriptions of each of the constructs—particularly the boundaries between them—it was necessary to focus on their distinguishing features in the search for examples. Additionally, focusing each construct on its forms or components (e.g., types of technology-content interactions) provided structure to the model cases section. While these definitions are simpler, they preserve the intent of each of the constructs, including the types of knowledge that are important in each one and emphasizing where they are different.

These definitions did not explore the differences between the constructs closely enough. While they highlight the distinctions, they do not fully define what those distinctions are. Therefore, I elaborated the framework using an analysis by Magnusson, Krajcik, and Borko (1999) and provided case examples to illustrate this elaborated model as described in the following chapter.

CHAPTER 5: AN ELABORATED MODEL OF TPACK

Conducting this conceptual analysis has helped to clarify both the definitions for and the boundaries between each of the constructs in the TPACK framework. For each construct, I have devised both an expansive and a simplified precising definition that demonstrates the complexity of the constructs (expansive) and then highlights the distinctions between them (précising). Additionally, the conceptual analysis has resulted in an elaborated model of the TPACK framework, deconstructing each of the constructs to its simplest features to facilitate the classification of examples. This model is informed by the analysis of PCK by Magnusson, Krajcik, and Borko (1999).

In their analysis, Magnusson, Krajcik, and Borko state that PCK includes knowledge of subject-specific strategies and topic-specific strategies. Subject-specific strategies are pedagogical methods that are unique to a given discipline, such as inquiry-based learning in science, investigations in mathematics, or primary source research in social studies. Topic-specific strategies are "specific strategies that are useful for helping students comprehend specific concepts" (p. 111). They further divide topic-specific strategies into topic-specific activities and topic-specific representations. Topic-specific activities are methods "that can be used to help students comprehend specific concepts or relationships; for example, problems, demonstrations, simulations, investigations, or experiments" (p. 113). While these activities may seem somewhat general (a demonstration can be used with any topic), the knowledge of the power of that particular activity to teach a particular topic changes the activity to a topic-specific one. Topic-specific representations include illustrations, examples, models, analogies, etc. These representations are concrete manifestations of a concept within a given subject area.

The addition of general strategies, as shown in Figure 5.1, makes the analysis by Magnusson, Krajcik, and Borko a good fit for clarifying the constructs in the TPACK framework. After completing the conceptual analysis, I used this structure to further clarify the definitions and boundaries for each construct.

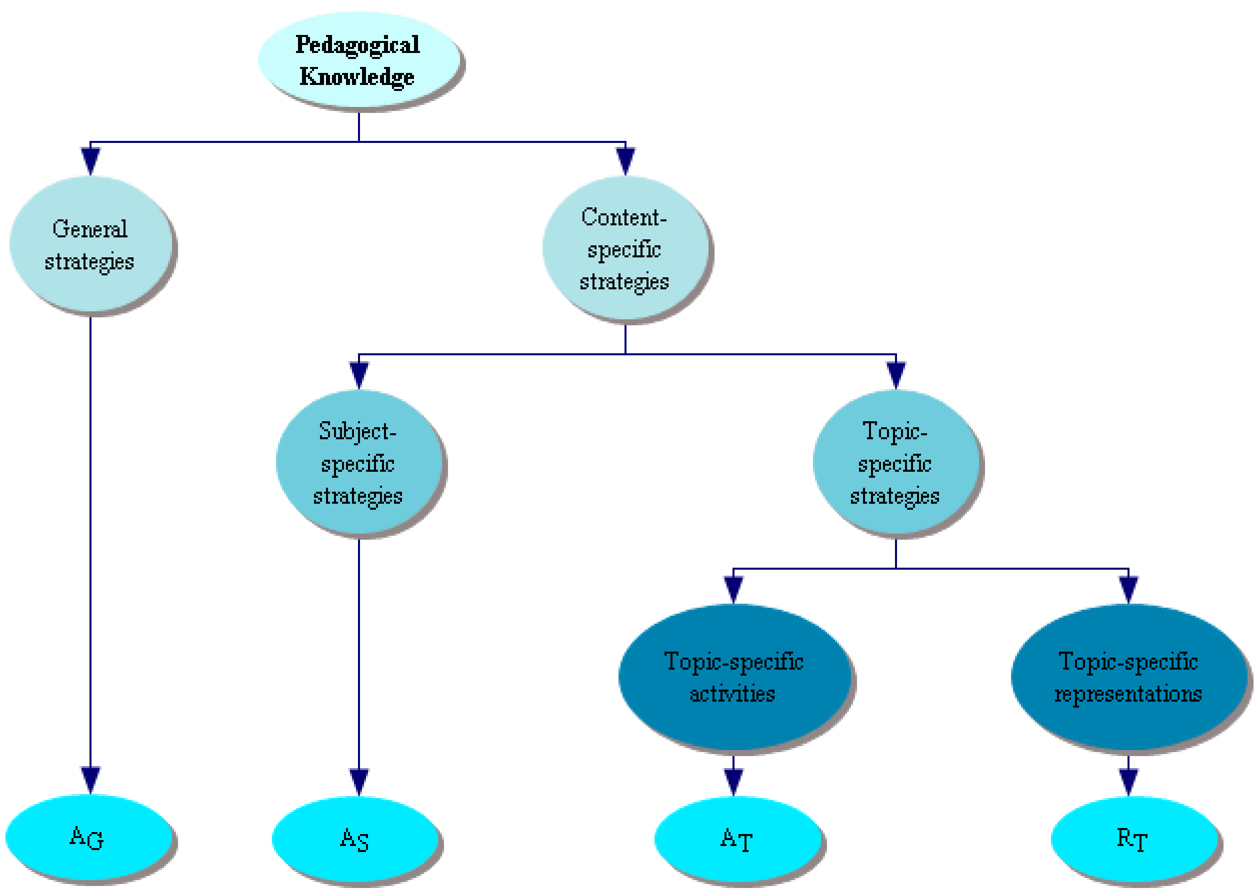

Figure 5.1. Pedagogical Knowledge informed by Magnusson, Krajcik, and Borko (1999).

Definitions

For each of the constructs, I have provided the expansive definition that resulted from the conceptual analysis, the precising definition from my revisions, and an explanation of how the analysis in Figure 5.1 applies to that construct. I have included all of the constructs in the TPACK framework in order to fully describe the elaborated model that I am proposing. A visual for the model is shown in Figure 5.2. Each element in the model is described in the subsequent sections.

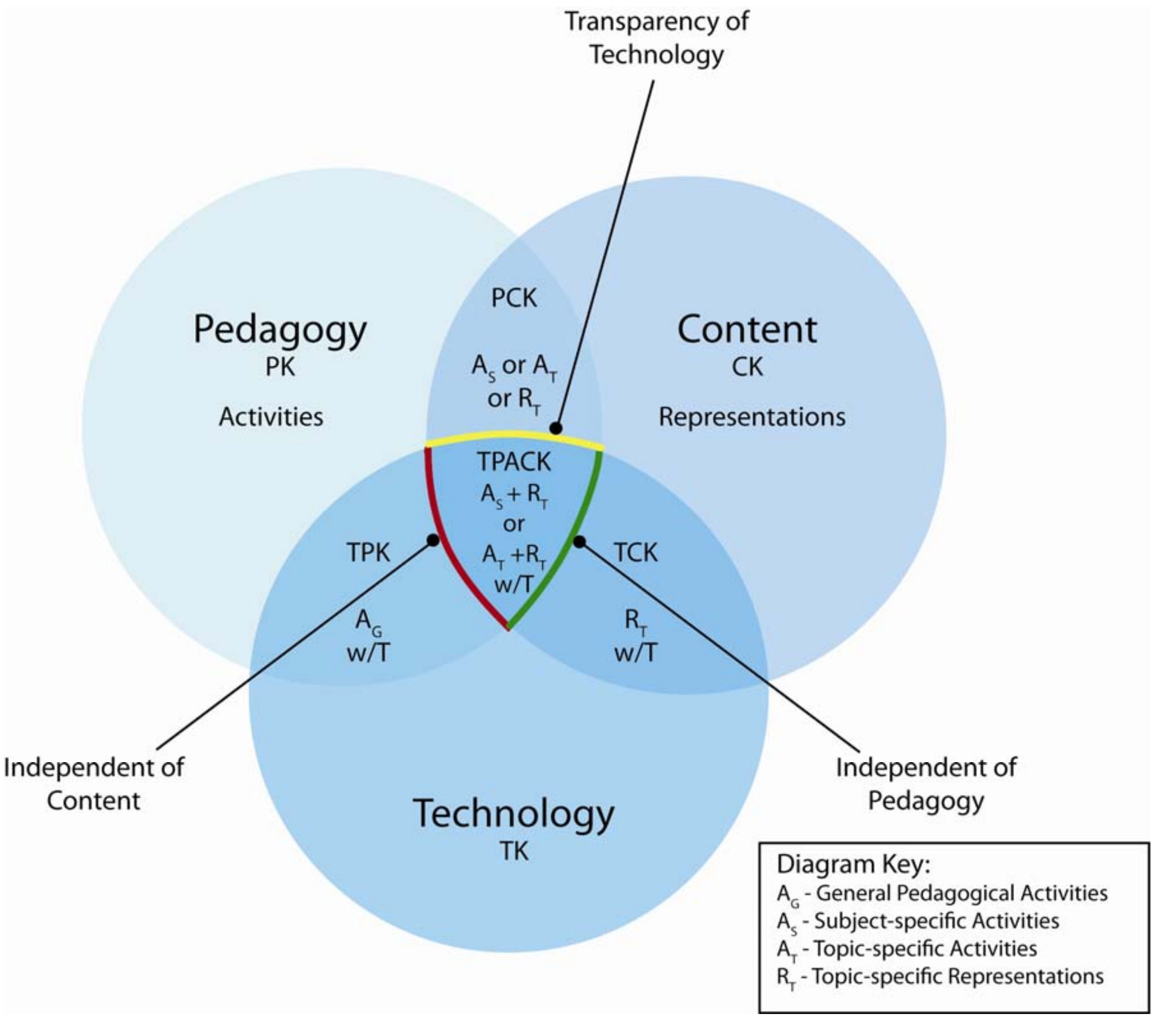

Figure 5.2. An elaborated model of the TPACK framework.

Pedagogical Knowledge (PK)

Grossman (1990) defined general pedagogical knowledge as “general knowledge, beliefs, and skills related to teaching” (p. 6). This broad definition encapsulates a very complex knowledge base including pedagogical methods, knowledge of learners, classroom management, and more. In the model I propose here, the definition of pedagogical knowledge is simplified to focus on a teacher's knowledge of the general pedagogical *activities* that she might utilize. General activities (A_G in Figure 5.2) are independent of a specific content or topic (meaning they can be used with any content) and may include strategies for motivating students, communicating with students and parents, presenting information to students, and classroom management among many other things. Additionally, this category includes general activities that could be applied across all content domains such as discovery learning, cooperative learning, problem-based learning, etc. Although this approach focuses on a narrower feature of pedagogical knowledge, examining pedagogy in this way helps to illuminate the differences between the constructs.

Referring to general pedagogical knowledge as being independent of content is somewhat misleading in that one cannot teach nothing. Pedagogical activities necessarily include some content (Morine-Dershimer & Kent, 1999). However, certain pedagogical activities can be generalized for use with multiple topics across multiple disciplines. This generalized knowledge allows teachers to be more efficient and effective as they can draw from a pool of activities that can be used across topics rather than create new activities for each topic.

Content Knowledge (CK)

Grossman (1990) defined content knowledge as "knowledge of the major facts and concepts within a field and the relationships among them" (p. 6). Again, this definition demonstrates that content knowledge involves complex understanding of the structures, questions, and processes within a discipline. For the purposes of this study, content knowledge is simplified to indicate a knowledge of the possible topic-specific representations (R_T in Figure

5.2) in a given subject area. These representations might include models of electron flow in science, graphs of data in mathematics, or timelines in social studies. This knowledge is independent of pedagogical activities or how one might use those representations to teach.

Pedagogical Content Knowledge (PCK)

Pedagogical content knowledge combines knowledge of activities and knowledge of representations in order to facilitate student learning. The knowledge of pedagogical activities here is content-specific rather than general because PCK is situated in a particular subject area. This knowledge is divided into knowledge of subject-specific activities and topic-specific activities. Subject-specific activities (A_S in Figure 5.2) can be used across topics in a given discipline, as described above. Topic-specific activities (A_T in Figure 5.2) are unique to teaching particular concepts within a discipline. According to Magnusson, Krajcik, and Borko, knowledge of topic-specific activities “includes teachers’ knowledge of the conceptual power of a particular activity,” meaning knowledge of how well that particular activity will work to help students understand that particular concept (p. 113).

Pedagogical content knowledge also includes understanding of the topic-specific representations (R_T) in a given discipline and how they might be used as part of the teaching activities to promote student learning. For example, does a particular model of electron flow help students better understand that concept? How does a graph help students understand the concept of slope? Or why might a timeline help students better grasp a particular historical era? Thus, a teacher with PCK knows how to utilize topic-specific representations in conjunction with subject- or topic-specific activities to help students learn.

Technological Knowledge (TK)

In this framework, technological knowledge is defined as knowledge of how to use emerging technologies. The definition is confined to emerging technologies in order to illustrate the difference between TPACK and PCK. In my interviews with the TPACK experts, several commented that the TPACK framework is a somewhat temporary one intended to draw attention to the technologies that teachers use. By defining technology as emerging technologies here, I hope to further focus the discussion on technologies that are not yet transparent in the context under consideration. For example, books were once considered technology—a tool that was easier to use and had more capacity than a scroll. It was not widely accepted and utilized right away, but after several hundred years, it is now so ubiquitous that no one thinks of it as a technology. The sliding nature of technology in the TPACK framework is demonstrated by the arrows in Figure 5.3 and will be discussed in more detail with each of the remaining constructs.

This study utilizes a definition of technology that is in keeping with previous TPACK studies. Koehler and Mishra define technology as "the tools created by human knowledge of how to combine resources to produce desired products, to solve problems, fulfill needs, or satisfy wants" (2008, p. 5). Thus, *technology* as it is used here encompasses any tool or collection of tools. I acknowledge that educational technologists have a broader conception of what technology is. This conception includes hard technologies (e.g., tools, devices, hardware) as well as soft technologies (e.g., methods, processes, etc.) (Heinich, Molenda, Russell, & Smaldino, 2002). For the purposes of this study, I chose to limit the definition of technology to those hard technologies or tools that an individual might utilize and exclude the concept of soft technologies as knowledge of those methods or processes is included in my earlier definition of pedagogical knowledge.

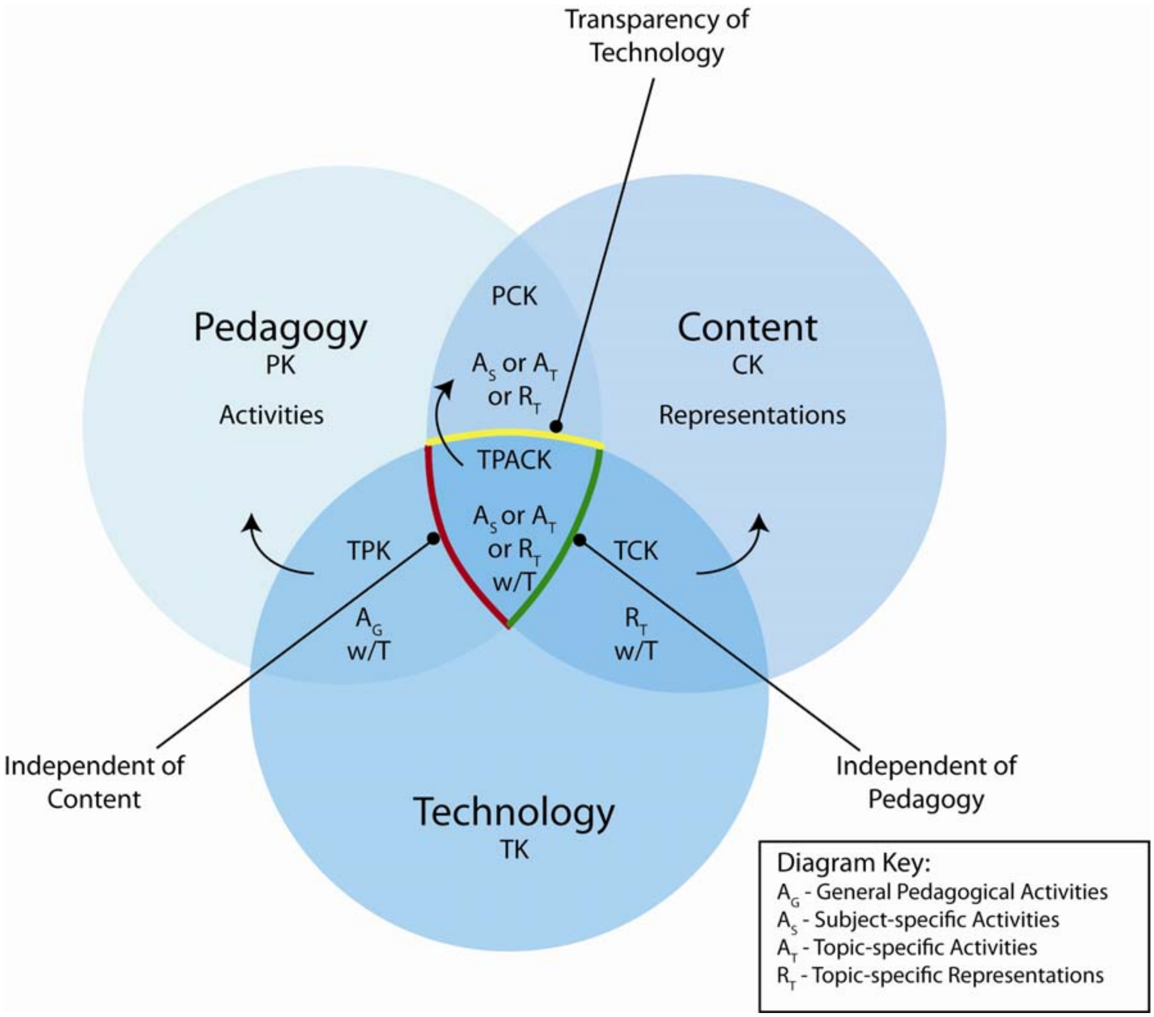

Figure 5.3. Illustration of the sliding nature of the TPACK framework.

Technological Content Knowledge (TCK)

TCK, TPK, and TPACK were included in the conceptual analysis that I conducted for this study. Therefore, the following sections contain three definitions for each of the constructs. First, I share the expansive definition that I created after the technical use analysis and interviews. These definitions serve to demonstrate the complexity of the constructs. Second, I have included the simplified precising definition that resulted from revisions after cases were explored for each of the constructs. These definitions help to focus the discussion on the distinctions between each of the constructs. Finally, I share the definition of each construct that corresponds with the elaborated model of the TPACK framework.

The expansive definition for TCK is a knowledge of appropriate technologies that may be utilized in a given discipline and how the use of those technologies transforms the content of that discipline through representation or the generation of new content or how the content of that discipline transforms or influences technology. This definition illuminates the complexity of the construct, acknowledging the aspects of TCK that were found in the literature as well as those found in my interviews with the TPACK experts as described in Chapter 4.

The simplified precising definition of this construct is a knowledge of the technology-content interaction independent of pedagogy. An individual with this type of knowledge understands the impact of technology on the representations of a discipline without a need to understand how those representations might be used in teaching. This definition brings focus to the construct, emphasizing its uniqueness from TPK and TPACK in that pedagogy does not play a role in it.

In the elaborated model of TPACK that I propose here, TCK refers to a knowledge of the topic-specific representations (R_T) in a given content domain that utilize emerging technologies. While the focus on representations does not fully represent the bidirectional relationship of content and technology, it does illuminate what I found to be the most practical and widespread form of TCK for teachers—knowledge of how to represent concepts with technology. The knowledge of these representations exists independent of knowledge about their use in a pedagogical context. As the technologies used in the representations become mainstream, that knowledge transforms into content knowledge. For example, graphing calculators were once considered emerging technologies in mathematics, but knowledge of how they facilitate mathematical representations is now part of the content of mathematics itself. Alternatively, software for three-dimensional modeling of numerical data, such as GraphCalc, is an emerging technology. Knowledge of how it facilitates content representation would be considered TCK, while knowledge of how the traditional graphing calculator facilitates those representations would be CK.

Technological Pedagogical Knowledge (TPK)

The expansive definition for TPK is a knowledge of the technologies that may be used in a generic pedagogical context, including the affordances and constraints of those technologies, and how those technologies influence or are influenced by the teacher's pedagogical strategies and student learning. This definition is again based on the literature and interviews as described in Chapter 4. It particularly emphasizes the bidirectional relationship between technology and pedagogy. It also highlights student learning, a common concern for teachers with PCK, TPK, and TPACK.

The simplified precising definition of this construct is a knowledge of the technology-pedagogy interaction independent of topic-specific representations or content-specific instructional strategies. An individual with this type of knowledge understands how technology could be used with general pedagogical strategies that could be applied independent of the specific content or topic being taught. These general pedagogical strategies are the same as those described under pedagogical knowledge. This definition emphasizes the distinction between TPK and both TCK and TPACK in that it does not focus on particular content and utilizes general pedagogical strategies rather than content-specific ones.

In the elaborated model, TPK is a knowledge of the general pedagogical activities (A_G) that a teacher can engage in using emerging technologies. Thus, TPK might include knowledge of how to motivate students using technology or how to engage students in cooperative learning using technology. Again, these activities are independent of a specific content or topic not because they don't involve content, but because they can be used in any content domain. As the technologies being used become transparent or ubiquitous, TPK transforms into pedagogical knowledge as the emphasis on the technology is no longer needed. For example, while the overhead projector was once considered a new tool that could be used in the classroom to facilitate presentation, its use in teaching is now mainstream. However, interactive whiteboards, which utilize digital projectors and allow the teacher and students to interact with projected content, are considered emerging technologies and are not yet ubiquitous in the classroom. Knowledge of how to use these interactive boards for general pedagogical purposes, then, would be considered TPK while knowledge of how to use the traditional whiteboard for the same purposes is PK.

Technological Pedagogical Content Knowledge (TPACK)

The expansive definition for TPACK is a knowledge of the dynamic, transactional negotiation among technology, pedagogy, and content and how that negotiation impacts student learning in a classroom context. This definition acknowledges the complexity of the interrelationship among each of the areas of TPACK with particular attention to student learning and context, all of which were emphasized in both the literature and the interviews as described in Chapter 4. Additionally, the phrase "dynamic, transactional negotiation" is one which Mishra argued uniquely captured the give-and-take that occurs as a teacher uses TPACK (P. Mishra, personal communication, May 2, 2008).

The simplified precising definition of this construct is a knowledge of the technology-pedagogy-content interaction in the context of content-specific instructional strategies and topic-specific representations. An individual with this type of knowledge understands the role of technology as part of content-specific instructional strategies to convey particular content representations. This definition quickly demonstrates that TPACK includes all three areas of knowledge. Additionally, it highlights the use of content-specific strategies, setting it apart from TPK (which utilizes general pedagogical strategies) and TCK which is independent of pedagogy. These content-specific strategies may include inquiry-based learning in science, primary source research in social studies, investigations in math, and more.

Based on the elaborated model of the framework, TPACK refers to a teacher's knowledge of how to coordinate the use of subject-specific activities (A_S) or topic-specific activities (A_T) with topic-specific representations (R_T) using emerging technologies to facilitate student learning. As the technologies used in those activities and representations become ubiquitous, TPACK transforms into PCK. For example, a teacher may know how to conduct a frog dissection with her students as part of inquiry-based learning in the classroom. Alternatively, she may know how to use an online dissection simulator with her students as part of inquiry-based learning in the form of a WebQuest. Knowledge of how to use the online simulator as part of her subject-specific activities is TPACK, while knowledge of how to conduct a traditional dissection with transparent technologies such as scalpels, paper diagrams, etc., is PCK. This "sliding" nature of TCK, TPK, and TPACK fulfills the vision of the researchers I interviewed that the framework may no longer be necessary once technologies are widely accepted. It also emphasizes the fact that there will always be a need for TPACK as long as there are new emerging technologies that have not yet become a transparent, ubiquitous part of the teaching profession's repertoire of tools.

The definitions and distinctions of the TPACK constructs provided by the elaborated model of the framework are more precise than those that have been indicated thus far in the literature and should facilitate the future identification and classification of examples of each of the constructs. While the expansive definitions demonstrate all of the essential features for each construct, the definitions in the elaborated model focus on those features that are particularly useful for distinguishing between the constructs.

Cases

The following three cases illustrate each of the constructs and how the model serves to differentiate between them. The first case comes from an interview with Dr. Summer Rupper, a faculty member in the Geology department at Brigham Young University. The second and third examples are a combination of real experiences and invented cases.

Case 1 – Representing Geological Concepts

This case is especially intriguing because it comes from a real, first-person account of how a teacher uses and thinks about technology. Dr. Rupper's interview revealed that she has strong and multifaceted knowledge of the role of technology in her field.

Case Vignette

Dr. Rupper is a scientist who studies glaciers throughout the world. When she is in the field, she uses both mechanical and electrical ice core drills to sample the ice so that she can better understand its composition. She also uses ice-penetrating radar to get a more accurate picture of the structure of the glacier as well as the ground beneath it. When she gets back to the laboratory, Dr. Rupper uses computers to analyze the numeric data gathered from the ice core drills and radar systems. Besides examining the numbers, she can also use software to create three-dimensional models of the glaciers and then test hypotheses about how different factors might change the size, position, or structure of the ice.

Dr. Rupper teaches both undergraduate and graduate-level geology classes. She often uses PowerPoint as a presentation tool in the classroom to help her stay organized and present information visually. Using PowerPoint helps her students focus on the most important concepts and helps her structure class discussions. Sometimes, she uses PowerPoint as a delivery tool for graphic representations. For example, one concept that has been difficult for her students to understand in the past is the difference between U- and V-shaped valleys. U-shaped valleys are carved by glaciers while V-shaped valleys are carved by rivers. To help teach this concept, she juxtaposes pictures of U- and V-shaped valleys side-by-side in a PowerPoint slide, helping students to visualize and discuss these types of erosion. But there is also content that she prefers to teach without using PowerPoint. For example, when she is teaching her students an equation, she will write it on the whiteboard as that allows her to teach it one step at a time.

In addition to her use of PowerPoint, Dr. Rupper also uses the three-dimensional models she creates in the lab as simulations for her students. She has tried in past semesters to teach her students through lecture and graphic representations about how a glacier can both advance and retreat, but neither strategy has worked. With the simulations, students can discover the concepts of advance and retreat by manipulating variables such as temperature and precipitation and watching the effects of those manipulations. Dr. Rupper feels that technology is very helpful, both for her work as a scientist and in her classroom teaching.

TCK

Dr. Rupper's work in the field and the laboratory reveals her knowledge of how technology can facilitate content-specific representations, as shown in Figure 5.4. The representations (R_T) in this vignette include how the ice core drills show the composition of the glacier, how the radar systems show the size and composition of the glacier, and how the software in the lab numerically and graphically represent the glacier. Dr. Rupper has knowledge of how technology facilitates the representation of her content in these specific ways. Her knowledge of these representations is independent of her knowledge of pedagogical activities that she may engage in with students.

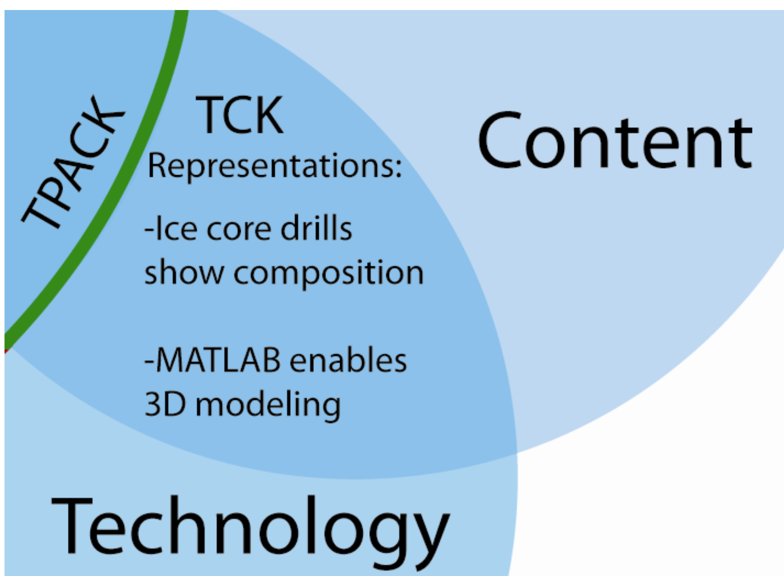

Figure 5.4. Dr. Rupper's knowledge of content-specific representations.

TPK

Dr. Rupper's knowledge of general pedagogical activities utilizing technology constitutes her TPK, as shown in Figure 5.5. The activity in this vignette that best demonstrates Dr.

Rupper's knowledge of general pedagogical activities (A_G) using technology is her knowledge of the use of PowerPoint as a presentation tool. In her interview, Dr. Rupper revealed that she uses PowerPoint to help her stay organized during her presentations. She also noted that it helps the students focus on the most important concepts in the lesson. Thus, she demonstrates knowledge of the general pedagogical reasons for utilizing this technology-enhanced activity independent of content.

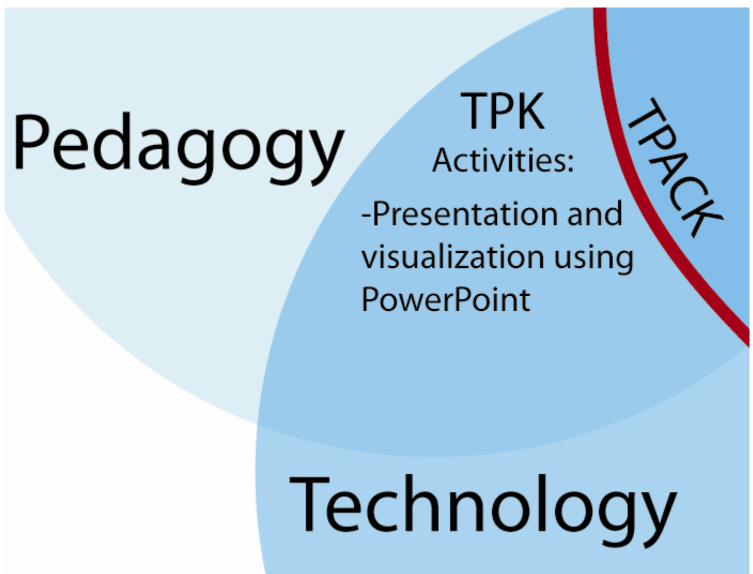

Figure 5.5. Dr. Rupper's knowledge of general pedagogical activities.

Knowledge of PowerPoint in a presentation activity might also be considered a borderline example (see Figure 5.6) in that some type of content will always be a part of the presentation. One cannot give a presentation on nothing. However, in Dr. Rupper's case, the focus of her knowledge is on the general purpose of the activity rather than the specific content being presented.

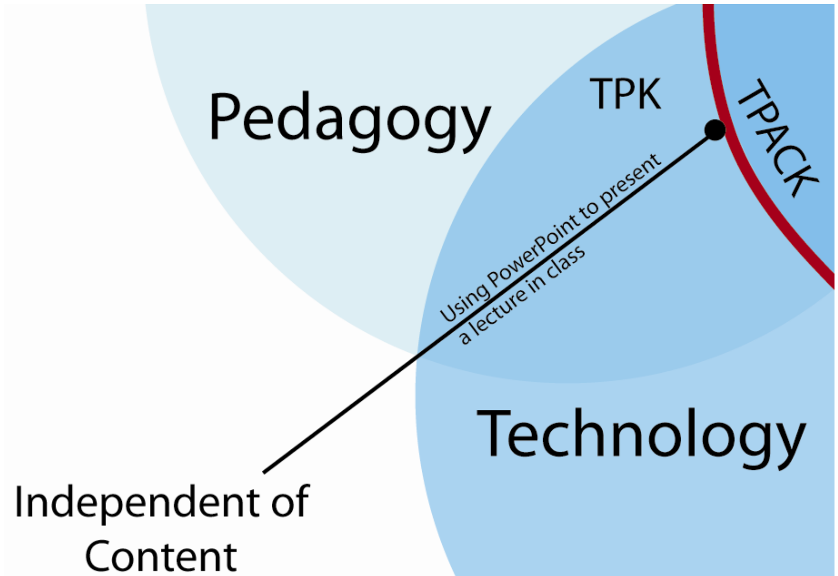

Figure 5.6. An example of Dr. Rupper's borderline TPK.

One might argue that PowerPoint is a transparent technology at the college level, making Dr. Rupper's knowledge PK rather than TPK. While PowerPoint is considered ubiquitous in business education (James, Burke, & Hutchins, 2006), that determination has not yet been made for other fields of study. Additionally, educators at all levels are still being trained in how to use PowerPoint effectively for student learning. In Dr. Rupper's case, she chooses to use PowerPoint rather than a traditional slide projector because of additional affordances in the program. This is a conscious decision, thus the technology is not yet transparent.

TPACK

Dr. Rupper's knowledge of how to coordinate technology, activities, and representations in the classroom to facilitate student learning constitutes her TPACK, as shown in Figure 5.7.

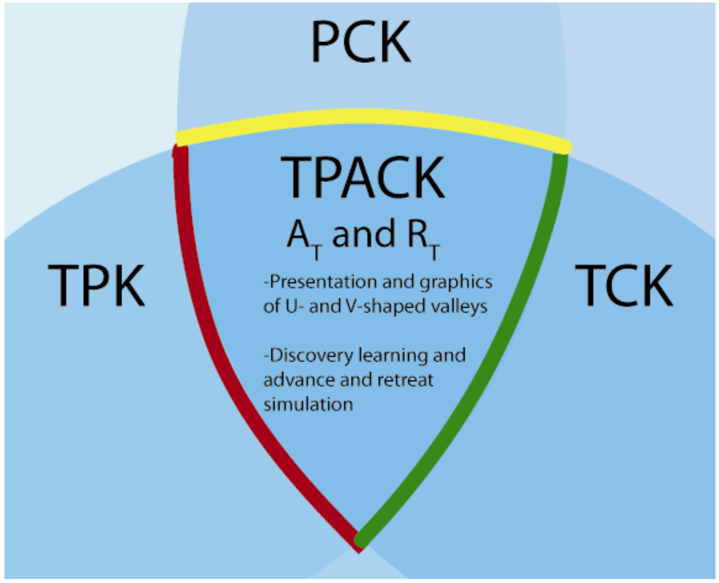

Figure 5.7. Dr. Rupper's knowledge of content-specific activities and representations.

First, Dr. Rupper knows that the difference between U- and V-shaped valleys is best taught through the presentation of specific graphic representations. Thus, the activity (A_G) involved is presentation while the representation (R_T) is graphics of the two valleys compared side-by-side. Though Dr. Rupper is utilizing what appears to be a general pedagogical activity, the representation is specific to the topic being discussed. Additionally, Dr. Rupper understands the "conceptual power" of the use of this activity with this particular representation. Thus, as proposed earlier, the presentation activity becomes a topic-specific activity (A_T) that she knows will work for the particular content she is teaching.

Second, Dr. Rupper knows that using a simulation in a discovery learning activity will help her students understand the concept of advancing and retreating glaciers. Here, the activity (A_G) is discovery learning and the representation (R_T) is a simulation of the glaciers. Again, the general activity of discovery learning is transformed into a topic-specific activity (A_T) with the use of a topic-specific representation and through Dr. Rupper's understanding of the "conceptual power" of this method.

As both a scientist and a teacher, Dr. Rupper is forced to examine the use of technology from a variety of perspectives. She considers how technology can help her represent her work in the field. She also considers how technology can help improve her teaching in general. Finally, she understands how technology can help her better represent content to students in her instruction. In the TCK example, Dr. Rupper's focus is on how technology enables the representation of her content. In the TPK example, her focus is on the general pedagogical activities that technology facilitates in the classroom regardless of content. In the TPACK examples, the focus is on both pedagogical activities and topic-specific representations that are facilitated by technology use.

Comparing the TCK and TPACK examples reveals that Dr. Rupper's TCK is independent of her knowledge of activities that she may engage in to teach her students. Because her TCK is very specialized in the area of geology and she is a practicing field researcher, it is not difficult for her to keep it separate from her pedagogical knowledge, though she may occasionally consider the need to teach her students various concepts that she learns in the field.

Comparing the TPK and TPACK examples reveals the transformative influence of topic-specific representations. Dr. Rupper's TPK clearly involves knowledge of general pedagogical activities enabled by technology. While the TPACK examples include the interaction between technology, content, and pedagogy, her pedagogical methods are general—in one case presentation and in the other discovery learning. However, the use of topic-specific representations effectually changes the general activities to topic-specific ones. Therefore, she is actually engaging in pedagogical strategies that she knows work for teaching this particular topic rather than taking a generic approach that happens to include representations of content.

Case 2 – Revitalizing History.

This case is a combination of invented examples and real teacher experiences that I discovered in the literature. It helps to demonstrate the use of content-specific instructional strategies in TPACK.

Case Vignette

Mr. Jorgensen, an eighth grade history teacher, hears about a technology called a *weblog* and learns how to create one. He reflects on how weblogs could impact historyand realizes that, if a lot of people keep weblogs, we could have numerous first-hand accounts of events, taking history out of the ivory tower and putting it in the voices of the individuals who lived it. He searches the Internet for weblogs by people in Israel, Iraq, China, New Orleans, and other places that are of current importance and is amazed at the powerful first-hand accounts of current events he finds on those blogs. Mr. Jorgensen thinks about how he could use weblogs with his students. He realizes that he could keep one for his classes with assignments, calendars, and other classroom management items. He could also have his students keep their own blogs to improve their writing and reflection and to motivate them to complete more professional work.

After testing out the class blog, Mr. Jorgensen decides to use weblogs to help his students understand that history is happening all around them and to help them see their place in it. They begin by reading a historian's account of an event, then a first person account of the same event. They talk about the difference in impact of the two. Then they search the Internet for weblogs written by students their age in other parts of the world that are currently playing a large role in world affairs. The students then create their own weblogs which they use to write about what's going on in the world around them, including direct links to and reflections about what the students whose blogs they are reading are going through. He is impressed by his students' progress in understanding and reflecting on world events.

TCK

Mr. Jorgensen's knowledge of how Web 2.0 technologies can transform the representation of history constitutes his TCK (see Figure 5.8).

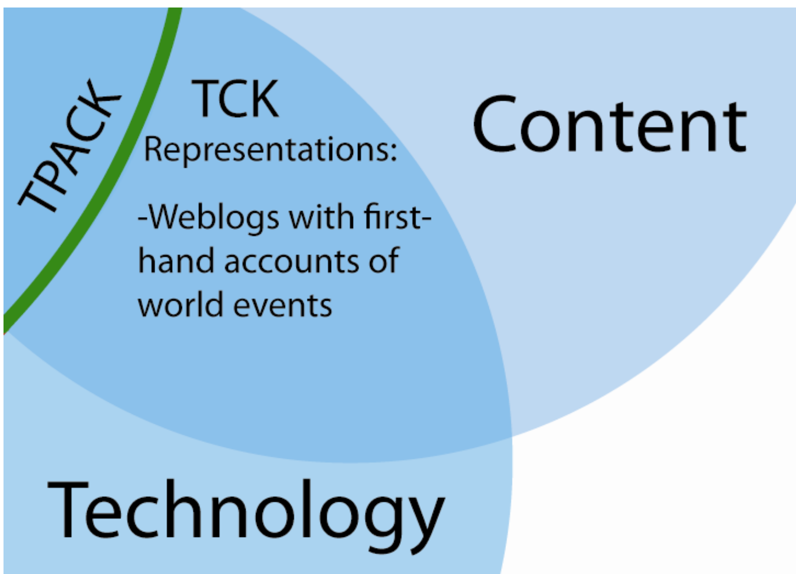

Figure 5.8. Mr. Jorgensen's knowledge of content-specific representations.

The representation (R_T) in this case is the concept of personal history in blog form. Just as personal history in a journal would be a representation, the technology of blogging has provided a new medium for personal history. Mr. Jorgensen perceives how blogs can represent history in a new and more dynamic way, independent of pedagogical activities he may engage in with his students.

TPK

Mr. Jorgensen's knowledge of how blogging might be used with general pedagogical strategies constitutes his TPK, as shown in Figure 5.9.

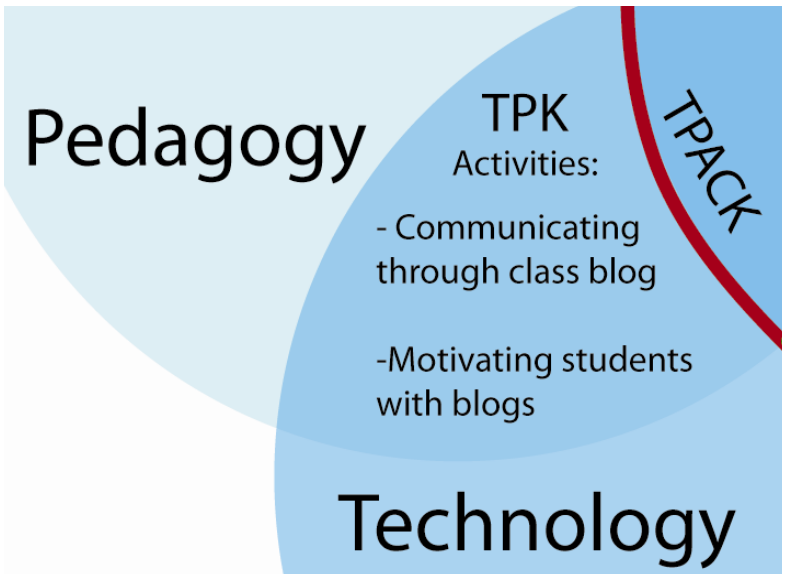

Figure 5.9. Mr. Jorgensen's knowledge of general pedagogical activities.

The activities (A_G) in this example are communicating with students through a class blog and motivating students to create better work through blogging. Using technology to motivate students and to communicate with students and parents are general pedagogical activities. In this example, Mr. Jorgensen uses blogs to facilitate those activities.

One may argue that the class blog will surely have historical content on it in the form of hyperlinks, videos, or Mr. Jorgensen's comments about the topic they may be learning about. This would constitute a borderline example, as illustrated in Figure 5.10. Mr. Jorgensen's focus in this case is on the activity of communication rather than on topic-specific representations using the blog.

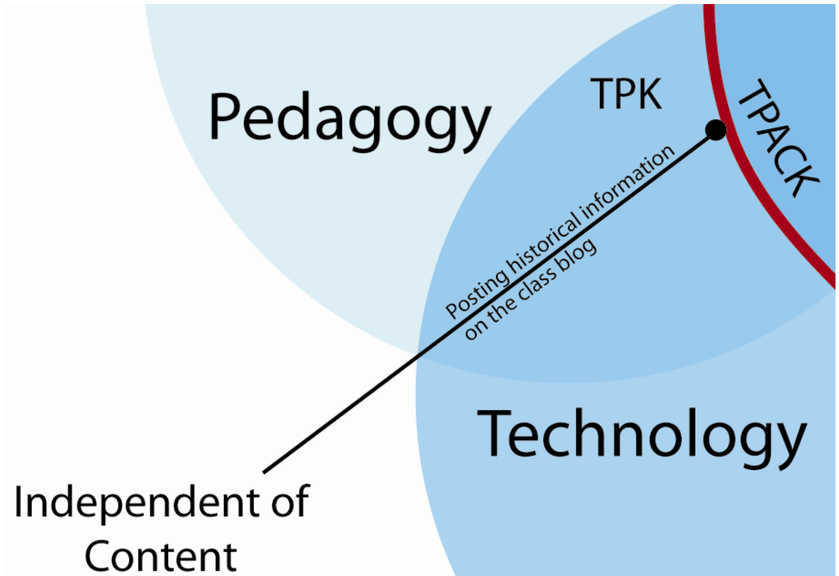

Figure 5.10. An example of Mr. Jorgensen's borderline TPK.

TPACK

Mr. Jorgensen's knowledge of the use of blogging in support of content-specific activities and representations constitutes his TPACK (see Figure 5.11). Here, the activity (A_S) is primary source research, a subject-specific pedagogical activity. The representation (A_T) is personal history facilitated by blogs. In this example, Mr. Jorgensen understands how blogs can help his students more readily access primary source accounts of current events. Thus, the focus is on both the research activity and the personal history representations.

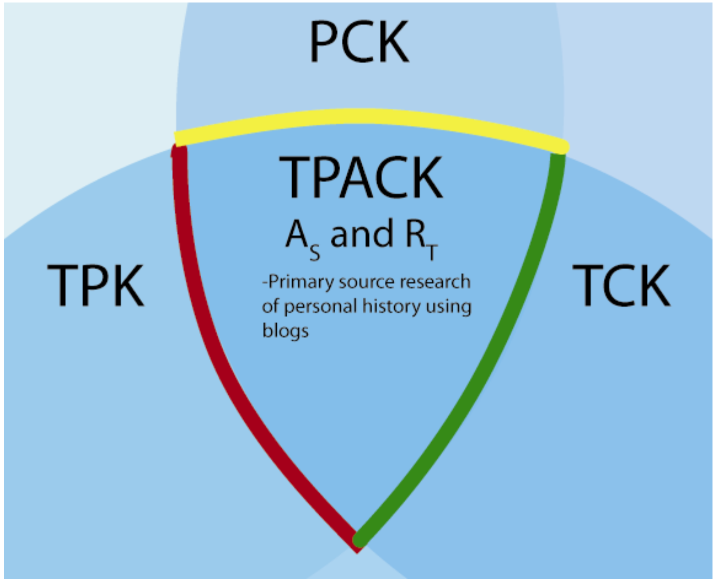

Figure 5.11. Mr. Jorgensen's knowledge of content-specific activities and representations.

Again, the examples of TCK and TPACK are distinguishable by the fact that pedagogical activities play no role in Mr. Jorgensen's TCK. Here, however, the distinction between his TPK and his TPACK is more obvious than it was in Dr. Rupper's case. In the TPK example, Mr. Jorgensen expresses knowledge of general pedagogical activities (using blogs to motivate and communicate with students). Using blogging as a novel communication tool is a strategy that is independent of any topic-specific representations. Meanwhile, his TPACK demonstrates understanding of the content-specific activity of primary source research, one that is fairly specific to history and not easily generalizable to other disciplines.

Case 3 – Becoming Scientists

The third case is also an example of real and invented experiences. As with case 2, it serves to illuminate the understanding of content-specific activities that is part of TPACK. This case is heavily based on the article "Leapin' Lizards! Students as Data Collectors" by Diane Petersen (2005).

Case Vignette

Mrs. Sharp, a fourth-grade teacher, attends a workshop where she learns how to use a GPS receiver and GIS software. Mrs. Sharp thinks that using the GPS receivers in class would help to motivate her students to participate more actively in her lessons. She thinks of multiple topics in her curriculum with which she could use the receivers, including geography (latitude and longitude), history (sites of historic events), and language arts (writing directions). She feels particularly that the existing science curriculum is fairly dry and has been looking for a way to spice it up. The workshop instructor tells Mrs. Sharp about how the GPS receiver helps biologists better track and map the habitats and movements of different species. After the workshop, Mrs. Sharp visits a few websites that reveal the impact of GPS technology on biological research. After the workshop, Mrs. Sharp writes a grant proposal and is able to purchase a set of six GPS receivers and the GIS software she needs. She makes a goal to use the GPS systems at least three times in the coming year.

Later that month, a student asks Mrs. Sharp how horned toads can be considered endangered when he sees them all the time in his backyard. Mrs. Sharp is inspired by this question and considers how she might have the students use the GPS receivers and GIS software as part of an inquiry-learning activity to map the horned toad population in their community. She knows that, in order for students to get the most from this activity, they will need to think like scientists. She structures the inquiry-based activity so that the students have to pose questions, conduct research, analyze the data, and present their findings. The students communicate with local farmers and gather data about horned toad sightings on their property. They also keep track of their own sightings. They then use the GPS receivers to pinpoint the locations of those sightings. Using the GIS software, they are able to create digital maps of the local horned toad populations. Additionally, they test hypotheses about the number of horned toads in their area, where they reside, what they eat, etc. Students then have the opportunity to share their findings with practicing biologists at local conferences. Mrs. Sharp is delighted by her students' transformation into scientists.

TCK

Mrs. Sharp's knowledge of how the GPS receivers and GIS software can help her represent content constitutes her TCK, as shown in Figure 5.12.

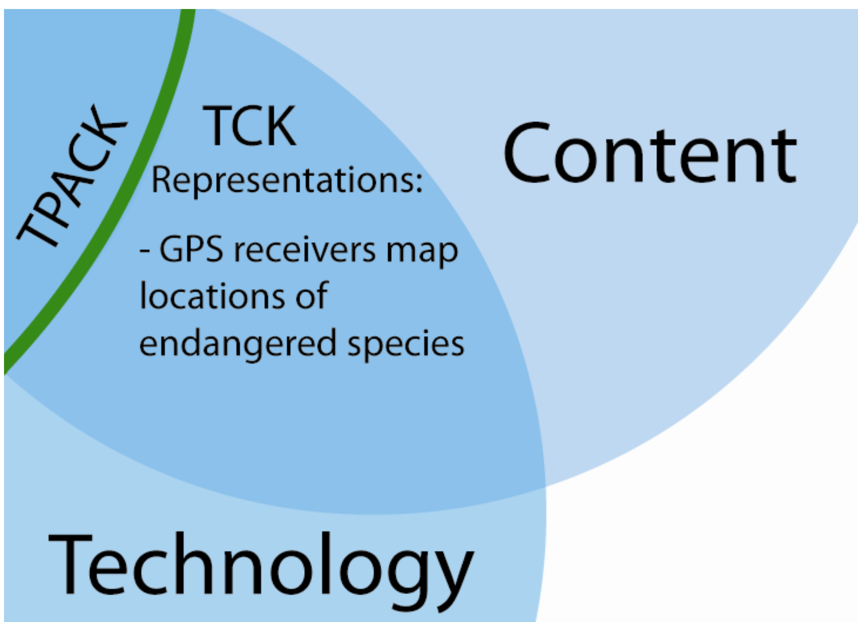

Figure 5.12. Mrs. Sharp's knowledge of content-specific representations.

In this example, the representations (R_T) are digital maps of the locations of various endangered species created by biologists. Mrs. Sharp understands how the GPS receivers and GIS software aid biologists in gathering data and representing their work. This knowledge is independent of her understanding of pedagogical activities.

TPK

Mrs. Sharp's knowledge of general pedagogical activities that might improve her students' motivation as well as her knowledge of classroom management as her students use the devices demonstrates her TPK (see Figure 5.13).

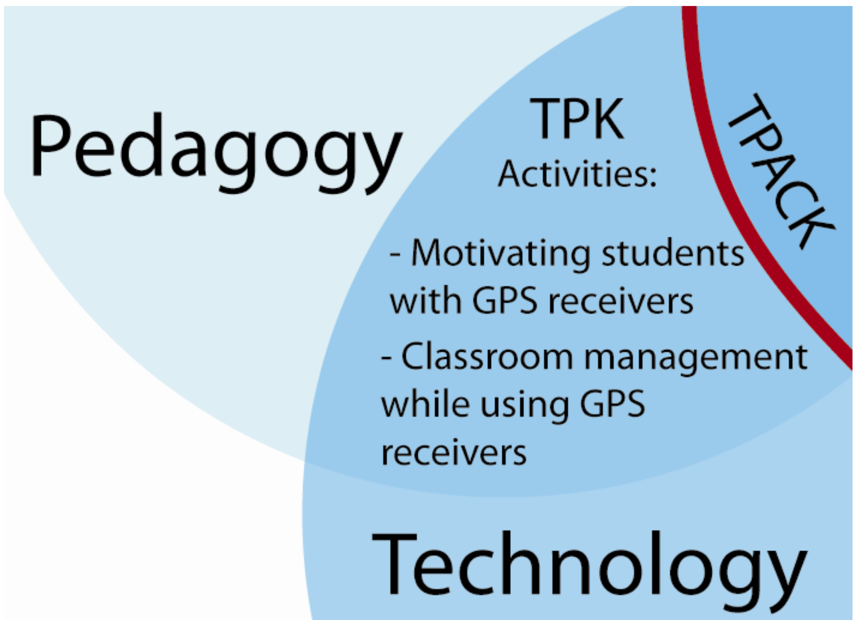

Figure 5.13. Mrs. Sharp's knowledge of general pedagogical activities.

Here, the activity (A_G) is using the GPS receivers to motivate students, independent of content. Mrs. Sharp has knowledge of how she can use GPS receivers as part of the general activity of motivating learners. As in the example of Mr. Jorgensen, while the GPS will most often be used in conjunction with content, the knowledge expressed here is focused on the activity of motivating students rather than on particular representations of content. Additionally, because Mrs. Sharp was only able to purchase six GPS receivers, her TPK includes knowledge about classroom management for the GPS activity. She must consider how the groups will be assigned, how she will provide instructions for the activity, where the activity will be carried out, etc. Thus she is using her TPK knowledge to facilitate good classroom management.

TPACK

Mrs. Sharp's knowledge of GPS receivers, science content, and content-specific pedagogical activities exemplifies her TPACK, as shown in Figure 5.14.

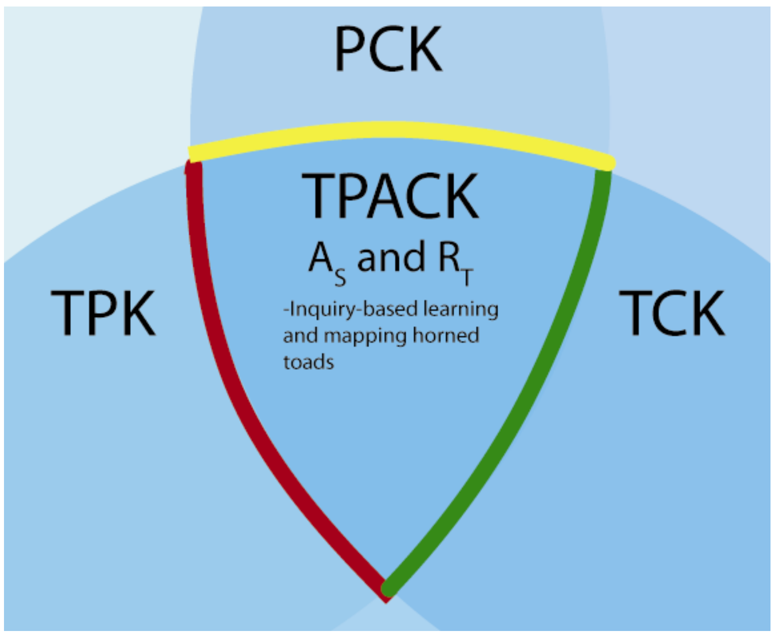

Figure 5.14. Mrs. Sharp's knowledge of content-specific activities and representations.

In this example, the activity is inquiry-based learning, a subject-specific activity (A_S) used particularly in science teaching. The representation (R_T) is a digital map of the locations of horned toads in the community. Here, Mrs. Sharp utilizes the GPS receivers and GIS software in conjunction with inquiry-based learning to help her students think like scientists. They pose questions, use the GPS receivers to gather data, use the GIS software to analyze that data, and then present their findings, just as real biologists do. This activity demonstrates to the students how real scientists use technology and inquiry to perform their work. Mrs. Sharp's TPACK is apparent in her ability to negotiate the relationship between technology and the activities and representations it facilitates.

Again, the difference between the TCK and TPACK examples is the presence of a pedagogical activity. In this case, the distinction between her TPK and her TPACK has two parts. First, the TPACK example includes representations of specific content through the GPS technology. Second, Mrs. Sharp utilizes her knowledge of the content-specific activity of inquiry learning to frame those representations.

These cases serve three purposes. First, they provide support for the proposed elaborated TPACK model that I have proposed, demonstrating that the basic distinction between the constructs is knowledge of activities and representations. Second, they help to clarify what some might consider borderline cases of the constructs, particularly through the illustration of the distinction between general pedagogical activities (for example, presentation) and topic-specific strategies (for example, presenting a specific representation in a way that has "conceptual power").Third, these cases illuminate how a teacher might have distinct TCK, TPK, and TPACK.

Discussion

Completing this conceptual analysis has resulted in a number of conclusions as well as unanswered questions. The following sections highlight some of those claims and issues.

Independence of the Constructs

While each of these cases includes examples of all three constructs, many that I found in the literature and online did not. A primary reason for this is the lack of detail in most examples, perhaps resulting from the fairly broad study of technology integration. I hypothesize that a person with TPACK will probably also have some degree of TPK and TCK. It is difficult to see how a knowledge of the interrelationship of activities and representations using technology can exist if that person does not have both a knowledge of activities with technology and a knowledge of content representations that utilize technology.

However, it may be possible for a person to have TPK or TCK without ever attaining TPACK. For example, an elementary school teacher may have a fair amount of TPK. He may understand how technology can be used as part of his general pedagogical activities – communication, motivation, presentation, classroom management, discovery learning, etc. – without being familiar with any content-specific representations. He uses PowerPoint to organize presentations, blogs to communicate, and drawing programs to motivate, but the focus is on the activity and not on specific representations of content.

Meanwhile, a mathematician may have a thorough understanding of how a computer algebra system can facilitate symbolic mathematics, demonstrating TCK. But that mathematician may never consider how she could use that computer algebra system in conjunction with a pedagogical activity to teach mathematics.

Pathways to TPACK

This research did not explore how teachers acquire TPACK. Some seem to believe that teachers should acquire TPK first, and then translate that into TPACK. Others believe that is wise for teachers to learn the technological representations in a given discipline (TCK) first, and then translate that into TPACK. Still others feel that teachers acquire TPACK directly, as that is the target knowledge. I believe that the acquisition of and pathways to TPACK are areas that warrant future research.

The question of how TPACK is acquired is a very important one for teacher education. Research in this area will shape the structure of technology integration and methods courses as teacher educators learn more about the most effective ways to help preservice teachers develop the skills and knowledge to negotiate the relationships among technology, pedagogy, and content. For example, if it is determined that developing TCK first leads to stronger TPACK, general technology integration courses may be eliminated in favor of integrating technology into the methods courses or creating a companion technology lab for the methods courses. Alternatively, if TPK leads to stronger TPACK, the general educational technology course may be strengthened. However, if research reveals that it is most effective for preservice teachers to develop TPACK directly, teacher educators will need to reform curriculum to integrate technology in every course.

TPACK at Different Grade Levels

Similarly, it is possible that elementary, secondary, and postsecondary teachers will differ in their TCK, TPK, and TPACK. While secondary and, particularly, postsecondary teachers specialize in a particular content area, elementary teachers tend to be generalists. Thus, it may be that elementary teachers have minimal TCK while secondary and postsecondary teachers have less TPK. If this is true, the pathways to TPACK discussed above may be different for different groups. While an elementary teacher may acquire TPK and then move into TPACK, a secondary or postsecondary teacher may begin with TCK and then develop TPACK. Again, further research is needed to determine the truthfulness of this theory. If this idea proves valid, researchers should examine if the difference in teacher knowledge is valuable and, if so, teacher education programs must be altered to emphasize this distinction. If the difference in teacher knowledge is not valid, teacher educators must help preservice and in-service teachers to more fully develop their TPACK.

The Need for Cases

These questions, as well as any others that persist regarding the TPACK framework, rely on detailed examples of teacher knowledge. These examples must be gathered with the TPACK framework in mind, ensuring that teachers will be prompted to discuss their reasons for using technology in specific cases. These detailed examples will help to further illustrate the framework and to elucidate its features.

The elaborated model of the TPACK framework proposed in this dissertation will be a valuable tool in this case study research. Scholars will be able to utilize the elaborated model to create observation checklists and interview protocols that will facilitate the classification of examples within the framework. Additionally, the parallel language of the model will facilitate description and discussion of these cases. Both of these contributions will make future qualitative studies on TPACK more replicable.

The Nature of Instructional Strategies in TPK and TPACK

While this study does not answer every question about the TPACK framework, it has illuminated several facets of it. One key finding is the nature of the instructional strategies involved in TPK versus TPACK. I propose that TPK involves a knowledge of general pedagogical strategies while TPACK involves knowledge of content-specific strategies. Additionally, the use of a topic-specific representation with a general pedagogical strategy transforms the nature of the strategy into a topic-specific one.

Emerging Versus Transparent Technologies in the TPACK Framework

Another result of this study is the perception of TPACK as a sliding framework. I hypothesize that as particular technologies become ubiquitous in the classroom, the focus on those technologies is no longer necessary. Thus, TPACK becomes PCK as the technology becomes transparent. While this is a new claim, it seems to be supported by the vision of TPACK as a somewhat temporary framework expressed in the interviews with TPACK researchers. Additional support for this perception is found in Shulman's early definitions of PCK which included technology as a pedagogical and curricular tool. It is possible that a narrower definition of technology (for example, as only digital tools) would impact this aspect of the elaborated model, but while TPACK researchers continue to perceive technology broadly, the distinction between emerging and transparent technologies serves a valuable purpose.

The Elaborated Model

A final result is the elaborated model of TPACK proposed above (see Figure 5.2). This model reduces the framework to its simplest components, emphasizing the distinctions between the constructs. I believe that this model will facilitate future research on the TPACK framework, particularly as researchers attempt to classify examples of teacher knowledge.

CHAPTER 6:

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

The TPACK framework has been both beneficial and problematic since its inception in 2005. While it has provided focus for researchers in the field of educational technology as well as emphasis on the use of technology in the classroom, the definitions of and boundaries between the constructs in the framework have been somewhat "fuzzy."

Completed Statement of Purpose

The purpose of this study was to seek definitions of and evidence for the component constructs of the TPACK model. This was accomplished through the use of the techniques of conceptual analysis. The technical use analysis allowed me to determine how each of the constructs has been defined and used in the literature to this point. Further interviews with leading TPACK researchers provided further clarification. The model cases provided examples of the center of each of the constructs, while comparing those model cases helped to clarify the boundaries between them. The borderline cases helped to test those boundaries as well as the new model for the TPACK framework that I proposed. Finally, the invented cases allowed me to demonstrate the efficacy of the definitions and model in the theoretical realm.

Completed Research Objectives

The following sections list each of the research objectives for this dissertation and describe how each of those objectives has been fulfilled.

Research Objective 1

Create stipulative definitions of technological pedagogical content knowledge, technological pedagogical knowledge, and technological content knowledge based on evidence from a conceptual analysis.

Pursuit of the first research objective resulted in both expansive and simplified precising definitions for each construct. The expansive definitions recognize the complexity of each construct while the simplified definitions help to emphasize the boundaries between the constructs and to support the new model of TPACK.

Research Objective 2

Elaborate examples of each construct.

Numerous examples of each construct were found through the technical use analysis, interviews, and search for model and borderline cases. These cases help to ground the framework in practical classroom experience. They also help to elucidate the constructs and the TPACK model.

Research Objective 3

Demonstrate the similarities and distinctions between these constructs through a graphic organizer.

The graphic organizer in Chapter 5 serves to illustrate the new model of the TPACK framework with particular emphasis on the similarities and differences between each of the constructs. This graphic organizer will be a useful tool for future researchers as they work to classify examples of TPACK.

Considerations for Future Research

While I believe that this study has helped to clarify the TPACK framework, there remain areas that are as yet unexplored or not fully understood. These areas should prove fruitful for future research on the TPACK framework.

First, I feel that it would be extraordinarily important to use these new definitions and the new model to conduct in-depth case study research with practicing teachers. The field would benefit from detailed examples of teachers' knowledge in practice and how it fits within the TPACK framework. These studies should be conducted with current teachers with all levels of technological knowledge and in all school situations—from wealthy suburban schools to struggling urban schools to spare rural schools. To get an accurate picture of those teachers' knowledge, the studies must include extended observation paired with interviews that aim at understanding the purposes and knowledge behind teacher action with technology.

Second, the connection between the grade level of the teacher and the levels of TCK/TPK are worth exploring in more detail. It is implied here that elementary teachers have stronger TPK and less TCK while college professors have stronger TCK. More evidence is needed to either support or refute this claim. This research has strong implications for the teaching of technology in teacher preparation programs. Findings regarding the composition of TPACK in elementary and secondary teachers would impact the structure of teacher education technology training.

Finally, of particular concern to myself and other whom I interviewed is how teachers acquire TPACK. Specifically, by which path do they arrive at that knowledge? Some seem to believe that teachers should first acquire TCK and then the TPACK will come as they enact their knowledge in a pedagogical context. Others feel that it is first necessary to have a knowledge of the general uses of technology in the classroom (TPK) before one can fully utilize subject-specific methods. Again, studies in this arena would have major implications for teacher preparation programs, particularly at the secondary level.

While I believe that this study has helped provide some clarity to the TPACK framework, there is still much work to do to fully understand the framework's complexity. Future research involving case studies and analysis of the development of TPACK as outlined here will have a major impact on how preservice and in-service teachers are trained to use technology in the classroom.

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APPENDIX A

INTERVIEW PROTOCOLS

Core Questions for TPACK Experts

TCK

1. What are your reactions to the definition and list of essential features for TCK?

2. Can you provide what you would consider to be a model example for this construct?

3. Do you conceive of all of these constructs within education or would you say TCK is not an educational construct?

4. What would it take to make the model example you provided for TCK an example of TPCK? What do you see as the differences between these constructs?

5. Are lists of products/sites appropriate for categorization within this framework or is it only appropriate to look at scenarios? If it is appropriate, which construct would these lists fall under? Does it depend on the context/intent of the list?

TPK

1. What are your reactions to the definition and list of essential features for TPK?

2. Can you provide what you would consider to be a model example for this construct?

3. What would it take to make the model example you provided for TPK an example of TPCK? What do you see as the differences between these constructs?

4. Again, the lists of products/sites appear in examples of TPK. Is this appropriate or are those examples missing the mark?

5. Does the nature of the instructional strategy play a role in TPK versus TPCK? For example, will TPK always consist of general pedagogical strategies like distance learning or cooperative learning or problem-based learning while TPCK will always utilize more content-specific strategies like inquiry-based learning or primary source research or balanced literacy methods?

TPCK

1. What are your reactions to the definition and list of essential features for TPCK?

2. Can you provide what you would consider to be a model example for this construct?

3. Is the distinction between TPCK and the other constructs often reduced to the level of detail provided in a scenario or is it really more than that? How much detail is required to make something TPCK versus TCK or TPK?

4. How can/should we address the idea of levels as we look at examples of TPCK? Should each example be first classified as belonging to one of the constructs and then as demonstrating a certain level of that construct? How can a person have "less" TPCK without it being just TCK or just TPK?

5. Do you think it's possible to measure TPCK and the other constructs using a quantitative instrument or is will we always need to use qualitative methods? What types of questions do you think would "get at" TPCK, TCK, and TPK on a survey?

Other

1. Do you consent to be a research subject as outlined in the informed consent document?

2. Would you be willing/available to conduct further reviews of my work on this project? The schedule is very tight, so the turnaround will be quick, but I'd love to have your input.

3. Would you like to be identified in the dissertation or would you rather remain anonymous?

Additional Questions

Questions for Grandgenett

1. Math is one subject area that is uniquely situated to observe TCK both outside of the educational context and inside it. Do you think that it's possible to have pure TCK in an educational context and, if so, what might that look like?

2. You mention "strong" TPCK – what is "strong" versus "weak" TPCK and how does it differ from TPK and TCK?

Questions for Lee

1. Social science is such a broad field. Do you think it's possible for social studies teachers, particularly at the elementary and jr. high school levels, to develop TCK?

2. Do you think that the teaching of critical media literacy skills is an example of TCK, TPK, TPCK, or something else entirely?

3. Shulman included technology in his discussion of Curriculum Knowledge. Do you think it is valuable to have a separate TPCK framework or would/could the same work be done/value added using the existing PCK framework?

Questions for Niess

1. You have been, as far as I can tell, the only person to really seriously address the issue of levels in TPCK. What was your motivation in doing that? How has it helped you?

University Professor Interview Protocol

Do you consent to be a research subject as outlined in the consent document I sent you?

Would you like to be identified in the dissertation or would you rather remain anonymous?

How do you use technology in your field work?

How has that technology influenced what you can do in your field?

How has that technology changed the content of your field?

How do you use technology in the lab?

How do you use technology in your teaching? Why?

Elementary Teacher Interview Protocol

Do you consent to be a research subject as outlined in the consent document I sent you?

Would you like to be identified in the dissertation or would you rather remain anonymous?

What is your current position?

How long have you been teaching?

What inspired you to use technology in your teaching?

Is technology a regular fixture in your teaching or do you use it only occasionally?

How do you use technology for preparation and productivity?

Do you generally focus on technologies that can be used across content areas or do you really get to know technologies and resources that are specific to each content area or both? Can you provide specific examples?

What is your thinking process as you prepare to teach a topic? What are the factors that affect your choice of technology?

Can you describe in detail some specific examples of how you have used technology in the classroom? Why did you choose to use technology in these ways? Please provide as much detail as possible.

How do you use technology to represent particularly difficult concepts?

How does technology influence your instructional methods and the content you are able to teach?

How does the content you teach influence the technology you choose?

Do you ever choose technologies to match a specific pedagogical strategy? Please explain.

APPENDIX B

DEFINITIONS OF THE CONSTRUCTS FOUND IN THE LITERATURE

Definitions of TCK Found in the Literature

"Understanding the impact of technology on the practices and knowledge of a given discipline." (Koehler & Mishra, 2008, p. 16)

"an understanding of the manner in which technology and content influence and constrain one another." (Koehler & Mishra, 2008, p. 16)

"Teachers need to understand which specific technologies are best suited for addressing subject-matter learning in their domains and how the content dictates or perhaps even changes the technology – or vice versa." (Koehler & Mishra, 2008, p. 16)

"the relationships between technology and content representations" (Koehler & Mishra, 2008, p. 21)

"how technological changes in our society affect these reconceptualizations of literacy" (102)

"what teachers know about how technology and subject matter knowledge are interconnected (Koehler & Mishra, 2005). Specifically, TCK for foreign language teachers is defined as the body of knowledge that teachers have about their target language and its culture and **how technology is used to represent this knowledge**." (113, emphasis added)

"knowledge about the manner in which technology and content are reciprocally related." (2006,1028)

"Teachers need to know not just the subject matter they teach but also the manner in which the subject matter can be changed by the application of technology." (2006, 1028)

"useful for describing teachers knowledge of how a subject matter is transformed by the application of technology (e.g., the use of simulations in physics)." (2005a, 134)

"The choice of technologies affords and constrains the types of content ideas that can be taught. Likewise, certain content decisions can limit the types of technologies that can be used. Technology constrains the types of possible representations but conversely affords the construction of newer and more varied representations. Furthermore, technological tools can provide a greater degree of flexibility in navigating across these representations.
Thus, we can define TCK as an understanding of the manner in which technology and content influence and constrain one another. Teachers need to master more than the subject matter they teach, they must also have a deep understanding of the manner in which the subject matter (or the kinds of representations that can be constructed) can be changed by the application of technology. Teachers need to understand which specific technologies are best suited for

addressing subject-matter learning in their domains and how the content dictates or perhaps even changes the technology—or vice versa." (Mishra & Koehler, 2007, p. 2220)

"An essential part of the role of the online instructor is to not only have a strong command of their subject matter (content knowledge), but also be able to design and deliver materials and activities in an electronic format for students (technological content knowledge)." (Archambault, 2008, 5192)

"that is technologies that could be considered new content in their disciplines." (Hughes, 2008, 5229)

"One short aside: the astute will notice that this modified model purports there is no such thing as an educationally-important "TC:" one cannot have meaningful expressions of technological content in education without first having a specific set of students, goals, and environment in mind (pedagogy). From page 1028 of the Mishra & Koehler (2006) paper: "Teachers need to know not just the subject matter they teach but also the manner in which the subject matter can be changed by the application of technology. For example, consider Geometer's Sketchpad as a tool for teaching geometry. It allows students to play with shapes and form, making it easier to construct standard geometry proofs." While I do not disagree that outside of education there may be room for a study of the pure interaction of content and technology, I believe that within education there is no such thing: to whit, even the example given by the authors assumes a certain age group, student skill-set, defined learning goals, and level of environmental support." (Robertson, 2008, 2219)

Definitions of TPK Found in the Literature

"an understanding of how teaching and learning changes when particular technologies are used. This includes knowing the pedagogical affordances and constraints of a range of technological tools as they relate to disciplinarily and developmentally appropriate pedagogical designs and strategies. This requires getting a deeper understanding of the constraints and affordances of technologies and the disciplinary contexts within which they function." (Koehler & Mishra, 2008, p. 16-17)

"an important part of TPK is developing creative flexibility with available tools in order to repurpose them for specific pedagogical purposes." (Koehler & Mishra, 2008, p. 17)

"TPK requires a forward-looking, creative, and open-minded seeking of technology, not for its own sake, but for the sake of advancing student learning and understanding." (Koehler & Mishra, 2008, p. 17)

"how to use digital tools to teach more effectively" (Koehler & Mishra, 2008, p. 21)

"knowledge of the existence, components, and capabilities of various technologies as they are used in teaching and learning settings, and conversely, knowing how teaching might change as the result of using particular technologies." (2006, 1028)

"knowledge of how technology can support pedagogical goals (e.g., fostering collaboration)." (2005a, 134)

"The pedagogy of how to use and apply the technology is technological pedagogical knowledge." (McCormick & Thomann, 2007, 2204)

"Technological pedagogical knowledge is an understanding of how teaching and learning changes when particular technologies are used. This includes knowing the pedagogical affordances and constraints of a range of technological tools as they relate to disciplinarily and developmentally appropriate pedagogical designs and strategies. This requires getting a deeper understanding of the constraints and affordances of technologies and the disciplinary contexts within which they function." (Mishra & Koehler, 2007, 2220)

"Thus an important part of TPK is developing creative flexibility with available tools in order to repurpose them for specific pedagogical purposes. TPK becomes particularly important because most popular software progra ms are not designed for educational purposes. Software programs such as the Microsoft Office Suite (Word, PowerPoint, Excel, Entourage, and MSN Messenger) are usually designed for a businesses environment. Furthermore, web-based technologies such as blogs or podcasts are designed for purposes of entertainment/communication/social networking. Teachers need to reject functional fixedness, and develop skills to look beyond the immediate technology and "reconfigure it" for their own pedagogical purposes. Thus TPK requires a forward-looking, creative and open-minded seeking of technology, not for its own sake, but for the sake of advancing student learning and understanding." (2220)

"ideas of how to use technology as a general pedagogical tool." (Hughes, 2008, 5229)

Definitions of TPACK Found in the Literature

not just in each of these key domains (T, P, and C) but also in the manner in which these domains interrelate, so that they can effect solutions that are sensitive to specific contexts." (18)

"Teachers constantly negotiate a balance between technology, pedagogy, and content in ways that are appropriate to the specific parameters of an ever-changing educational context." (21)

"how to use technology to help students learn a particular topic" (21)

"a true understanding of the intersection of knowledge about technology, content (content areas or subjects such as mathematics, science, or English), and pedagogy (specific instructional practices that are effective for teaching the subject. Teachers with high levels of TPCK possess not only general technology skills, but also knowledge about the types and specific uses of technology that are most likely to facilitate teaching and learning in each subject." (51)

"always applied in the context of a specific, idiosyncratic teaching-learning situation, and its effectiveness is highly dependent on the extent to which teachers are able to pedagogically accommodate that context." (51)

"While the teacher may be able to select from a menu of prefabricated or 'canned' strategies, at a minimum these have to be tweaked on the spot to fit the current context." (56)

"how technology might be used to teach literacy more effectively or how technology might change the way students actually learn to read and write" (61)

"the connections and interactions between the knowledge of content, pedagogy, and technology with respect to teaching literacy" (62)

"For K-6 literacy, good teaching with technology will look very different for individual teachers who teach students with diverse instructional needs." (71)

"thoughtfully consider how to best connect literacy content and technology with research-based practices in their classrooms." (72)

"Teachers must be prepared to plan for and then facilitate learning environments where elementary students are engaged with learning literacy using proven pedagogical and technological approaches." (77)

"E-TPCK and TPCK in general are *temporary* concepts that draw attention to the interconnections between technological tools, concepts, activities, and perspectives and the well-developed teacher knowledge, content knowledge, pedagogical knowledge, and pedagogical content knowledge." (88)

“adaptive to conditions and context.” (90)

“understand, consider, and choose to use technologies when they uniquely enhance the curriculum, instruction, and/or students’ learning in a subject matter area.” (103)

“a framework that incorporates the indispensable trait of an educator’s knowledge as he/she integrates technology into his/her teaching practice at the same time as attending to the complexities of this particular kind of knowledge. TPCK is an emergent form of knowledge as a response to the growing need for a scaffold that supports the sound integration of technology. TPCK is not an extension or appendix of content, pedagogy, and technology but rather a complex form of knowledge that blends all three components and the dynamic relationships that exist among them.” (117)

“it is a matter of thinking imaginatively about ‘how’ technology may support teaching and learning more than focusing too much on ‘what’ technologies may be used.” (118)

“separately conceitve of technology, pedagogy, and content and then consider their interplay.” (129)

“teachers might also enhance, transform, or otherwise reorganize social studies subject matter given technological pedagogical contexts.” (131)

“a teacher decides and plans for appropriate use in their classroom given knowledge of learners, knowledge of curriculum, the needs of the school community, and the goals or purposes of the course and subject.” (132)

“an emergent form of knowledge that goes beyond all three components (content, pedagogy, and technology). This knowledge is different from knowledge of a disciplinary or technology expert and also from the general pedagogical knowledge shared by teachers across disciplines. TPCK is the basis of good teaching with technology and requires an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students’ prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones.” (2006, 1028-1029)

“’TPCK represents a class of knowledge that is central to teachers’ work with technology. This knowledge would not typically be held by technologically proficient subject matter experts, or by technologists who know little of the subject or of pedagogy, or by teachers who know little of that subject or about technology.’” (2006, 1029)

“The core of our argument is that there is no single technological solution that applies for every teacher, every course, or every view of teaching. Quality teaching requires developing a nuanced understanding of the complex relationships between technology, content, and pedagogy, and using this understanding to develop appropriate, context-specific strategies and representations." (2006, 1029)

"if we jointly consider all three elements (T, P, and C), we get *Technological Pedagogical Content Knowledge* (TPCK). True technology integration, we argue, is understanding and negotiating the relationships between these three components of knowledge. Good teaching is not simply adding technology to the existing teaching and content domain. Rather, the introduction of technology causes the representation of new concepts and requires developing a sensitivity to the dynamic, transactional relationship between all three components suggested by the TPCK framework." (2005a, 134)

"We argue that intelligent pedagogical uses of technology require the development of a complex, situated form of knowledge we call Technological Pedagogical Content Knowledge (TPCK)." (2005b, 95)

"At the heart of TPCK is the dynamic, transactional relationship between content, pedagogy, and technology. Good teaching with technology requires understanding the mutually reinforcing relationships between all three elements taken together to develop appropriate, context specific strategies and representations." (2005b, 95)

"TPCK helps teachers define the best uses of technology to effectively teach mathematics or social studies or reading, and emphasizes the fact that the technology used and the approach will be quite different for each content area. Thus, the way a skilled teacher effectively uses technology for teaching science will look quite different than the way a skilled teacher effectively uses technology to teach history. Differences include both the type of technology used and the pedagogy involved." (Thompson, 2005, 46)

"for technology to become an integral component or tool for learning, science and mathematics preservice teachers must also develop an overarching conception of their subject matter with respect to technology and what it means to teach with technology – a technology PCK (TPCK)." (Niess, 2005, 510)

"the integration of the development of knowledge of subject matter with the development of technology and of knowledge of teaching and learning." (Niess, 2005, 510)

"TPCK for teaching with technology means that as teachers think about particular mathematics concepts, they are concurrently considering how they might teach the important ideas embodied in the mathematical concepts in such a way that the technology places the concept in a form understandable by their students." (Niess, 2006, 196)

"social studies students are using disciplinary content knowledge that is culled from the real world and pedagogically repackaged to enable democratic experiences." (141)

"As Mishra and Koehler argued, realizing the potential of the technology requires skills and knowledge not just of technology, pedagogy, and content in isolation but rather of all three taken together. Teaching successfully with technology requires continually creating, maintaining, and re-establishing a dynamic equilibrium among all three components. Teachers constantly negotiate a balance between technology, pedagogy, and content in ways appropriate to the specific parameters of an ever-changing educational context. Teachers construct curricula through an organic process of iterative design and refinement, negotiating among existing constraints to create contingent conditions for learning." (Bull, et al, 2007, p. 130)

"that technology should be introduced in the context of content instruction and that teachers should take advantage of the unique features of technology to teach content in ways they otherwise could not (Garofalo et al., 2000). If the pedagogical content knowledge required for each discipline differs, it follows that the ways in which technology might best be used for each discipline may also differ." (131)

"Our point here is that the full range of possibilities should be employed, matching the tool to the pedagogical goal and need" (135)

"TPCK involves an awareness of the strategies that incorporate the use of technology to create a student-centered learning environment, and is focused in the overlapping areas of content knowledge, pedagogical knowledge, and technology (Mishra & Koehler 2006). It is the link between the use of technology as a performance tool and the use of technology within a teaching strategy as a pedagogical tool." (Cavin & Fernandez, 2007, 2180)

"To effectively make such decisions requires an understanding of the interaction of the three components of TPCK: the technology, the pedagogy related to teaching a specific content, and the content itself." (2180)

"TPCK refers to a true understanding of the intersection of three kinds of knowledge: knowledge about technology, content knowledge (knowledge about subjects such as mathematics, science or English), and pedagogical knowledge (specific instructional practices that are effective for teaching each subject) (Koehler and Mishra, 2007). Teachers with high levels of TPCK possess not only general technology skills, but also knowledge about the types and specific uses of technology that are most likely to facilitate the teaching and learning of each subject. TPCK is always applied in the context of a specific, idiosyncratic teaching-learning situation, and its effectiveness is highly dependent on the extent to which teachers are able to pedagogically accommodate that context." (Kelly, 2007, p. 2199)

"it is important that teachers' TPCK includes knowledge and skills in identifying and appropriately responding to differential levels of access to technology among students. In this regard, an entry level TPCK skill teachers should possess, across content areas, is the ability to obtain, at the start of a class, information about the technology access of students." (2200)

"The integration of choosing the appropriate pedagogy for teaching content and technology and the appropriate technology for the content is TPCK." (McCormick & Thomann, 2007, 2204)

“TPCK is an emergent form of knowledge that goes beyond all three components (content, pedagogy, and technology). Technological pedagogical content knowledge is an understanding that emerges from an interaction of content, pedagogy, and technology knowledge. Underlying truly meaningful and deeply skilled teaching with technology, TPCK is different from knowledge of all three concepts individually. We argue that TPCK is the basis of effective teaching with technology and requires an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students’ prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones. By simultaneously integrating knowledge of technology, pedagogy and content, TPCK is a form of knowledge that expert teachers bring into play any time they teach. Each “wicked problem” or situation presented to teachers is a unique combination or weaving together of these three factors, and accordingly, there is no single technological solution that applies for every teacher, every course, or every view of teaching. Rather, solutions lie in the ability of a teacher to flexibly navigate the space defined by the three elements of content, pedagogy, and technology and the complex interactions among these elements in specific contexts. Ignoring the complexity inherent in each knowledge component, or the complexity of the relationships among these components can lead to oversimplified solutions or failure. Thus, teachers need to develop fluency and cognitive flexibility not just in each of these key domains (T, P, and C) but also in the manner in which these domains interrelate, so that they can effect solutions that are sensitive to specific contexts. This is the kind of deep, flexible, pragmatic and nuanced understanding of teaching with technology that we advocate.” (2220-2221)

“TPCK, interconnection and intersection of content (mathematics), pedagogy (teaching and student learning), and technology (spreadsheets) (Margerum-Leys & Marx, 2002; Mishra, & Koehler, 2006; Niess, 2005; Pierson, 2001; Zhao, 2003), is that mode of thinking that integrates these multiple domains of knowledge in ways that rely on planning, organizing, critiquing and abstracting ways to integrate technologies such as spreadsheets with specific mathematical content and specific student needs.” (Niess, 2007,

“TPCK emphasizes teachers’ knowledge of the connections, interactions, affordances, and constraints between and among technology, pedagogy, and content. The theory also specifies the importance of how and in what context teachers learn to integrate technological with pedagogical and content knowledge. A key component of TPCK is the “Learning Technology by Design” approach where teachers participate in “design teams” comprised of individuals with varying expertise in content, pedagogy, and technology, to develop technological solutions to authentic problems of practice.” (Peruski, Mishra, & Koehler, 2007, 2208)

“pedagogy, and technology are no longer independent of each other, and members can develop contextualized, domain-specific strategies and representations.” (Sun & Deng, 2007, 2270)

“We believe that technology can inform pedagogical practices appropriate to the epistemological considerations of the content in part by opening up opportunities previously unavailable.”

(Wellman & Snow, 2007, 2280)

“use technology as an instructional tool within their content areas” (Hardy, 2008)

“involves an understanding of the complexity of relationships among students, teachers, content, technologies, practices, and tools.” (Archambault, 2008, 5190)

“These include technical considerations (technological aspects that impact the extent to which technology facilitates student learning), differences in online pedagogy (the differences in teaching strategies that have to be implemented when adapting curriculum to a distance environment, involving issues such as student interaction, evolving teacher roles, student access, and evaluations of student outcomes), and principles of instructional design (sufficiently knowing a particular content to be able to use adopted technology to develop and offer quality online instruction).” (5191)

“Simply using technology in the classroom does not represent TPCK. Using technology in a manner that enhances student learning by employing specific technological tools and using specific technology-related teaching strategies in presenting a content lesson does.” (Cavin, 2008, 5214)

“TPACK refers to the idea that learning occurs best when teachers engage in equal parts of knowledge of technology, knowledge of content, and knowledge of pedagogy in their instruction” (Fath & Genalo, 2008, 4690)

“the special form of knowledge helping teachers know how to use particular technologies to teach content-specific concepts” (Hughes, 2008, 5229)

“While the intersection of content, pedagogical and technological knowledge is a necessary condition for effective integration of technology into instruction, it is not a sufficient condition. Teaching with technology, like all other teaching, does not occur in a vacuum. It occurs in a teaching-learning context that is rich in characteristics—physical, social, psychological, cultural. These characteristics can interact with content, pedagogy and technology in unique ways to affect the achievement of learning outcomes. Therefore, in addition to content, pedagogy and technology, the teaching-learning context, hereafter referred to as *the context,* is a fourth area of knowledge teachers must incorporate into their TPACK-based instructional designs if these are to be effective with all children.” (Kelly, 2008, 5257)

“Instructional design based on the TPACK framework should be concerned about incorporating, responding to, and influencing the context and through it, the psycho-social functioning and achievement of all students.” (Kelly, 2008, 5258)

“teachers need a knowledge that exists in the intersection of Technology, Pedagogy and Content” (Leatham, 2008, 5277)

“TPCK is different from the technological knowledge. It is a kind of integrated knowledge system supported by PCK and the knowledge about technology simultaneously" (Lin et al, 2008, 4730).

"Although the definition and extent of TPCK are still in controversy, the researchers of this project attempt to sum up the rationale into 5 categories as described below.
1. Belief: The value and opinion about technology embedded teaching hold by a teacher.
2. Evaluation: Whether a teacher know how to evaluate students' learning achievement through technological tools.
3. Content: How a teacher gets information about the content knowledge s/he will teach by utilizing technology tools.
4. Design: How a teacher transfer content knowledge to curriculum or teaching activities through technology.
5. Representation: How a teacher uses proper technological tools to represent knowledge or concepts in her/his course." (4731)

"Thus, to implement TPCK correctly, it is important to first understand what content to target, and then develop appropriate pedagogy and technology to facilitate meaningful learning" (McGuire, et al, 2008, 2119)

"Technological, pedagogical, and content knowledge (TPACK) describes that body of knowledge that teachers need for teaching with and about technology in their assigned subject areas (such as mathematics) and grade levels. TPACK (previously called technological pedagogical content knowledge or TPCK) is depicted as knowledge that relies on the interconnection and intersection of content, pedagogy (teaching and student learning), and technology. TPACK must be viewed as more than a set of multiple domains of knowledge and skills that teachers need for teaching their students particular subjects at specific grade levels. TPACK is a way of thinking that integrates these multiple domains of knowledge of mathematics, pedagogy and technology, but it is more than simply knowledge of these three domains of knowledge." (Niess, 2008, 5297)

"Considering the goal of engaging students in mathematical problem solving, a mathematics teacher's TPACK must focus thinking strategically in planning, organizing, implementing, critiquing results and abstracting plans for specific mathematics content and diverse student needs." (5297)

"Niess further clarified these central components of TPACK as the knowledge and beliefs that a mathematics teacher demonstrates that is consistent with:
1. An overarching conception about the purposes for incorporating technology in teaching mathematics.
- This conception is what the teacher knows and believes about the nature of mathematics, what is important for students to learn, and how technology supports learning mathematics. These foundations of the teacher's knowledge and beliefs about teaching mathematics 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 with

technology.
In this area, the teacher relies on and operates from knowledge about how students learn mathematics with technologies and believes that technologies are useful in learning appropriate mathematics.
3. Knowledge of curriculum and curricular materials that integrate technology in learning and teaching mathematics.
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 with technologies.
With respect to teaching and learning, the teacher adapts mathematical representations with technologies in multiple ways to meet specific instructional goals and the needs of the breadth of learners in the class." (5298)

"Teachers do not demonstrate that they either have or do not have TPACK for teaching mathematics with appropriate technologies. They differ in their actions with respect to each of the components as they are confronted with whether to accept or reject the use of various technologies in teaching mathematics. Their differences are a function of their knowledge of mathematics, their knowledge of the technologies, and their knowledge of teaching and learning (pedagogy)." (5298)

"From this perspective, teachers' development of TPACK for teaching mathematics with appropriate technologies such as spreadsheets is a developmental process." (5269)

"Early studies (Niess et al., 2006) on continuing in-service education directed at developing teachers' TPACK preparing them for teaching mathematics with spreadsheets described these five levels of teachers' TPACK for teaching mathematics with spreadsheets using ideas from Rogers' (1995) five levels:
1. *Recognizing* (knowledge) where teachers are able to use the technologies and recognize alignment of the capabilities of the technologies with mathematics content.
2. *Accepting* (persuasion) where teachers form a favorable or unfavorable attitude toward teaching and learning mathematics with appropriate technologies.
3. *Adapting* (decision) where teachers engage in activities that lead to a choice to adopt or reject teaching and learning mathematics with appropriate technologies.
4. *Exploring* (implementation) where teachers actively integrate teaching and learning of mathematics with appropriate technologies.
5. *Advancing* (confirmation) where teachers evaluate the results of the decision to integrate teaching and learning mathematics with appropriate technologies." (5299)

"The concept of integrating technology with the more traditionally held notions of teacher work, pedagogy and content, ensures that a technology-integrating teacher capable of using any appropriate tools to supplement teaching of 21st century skills is indeed the goal of all teacher preparation." (Pierson, 2008, 5305)

“This short paper recommends the formal inclusion of “context” as an additional class of knowledge in the “Technological Pedagogical Content Knowledge” (TPCK) framework” (Reeve, 2008, 5310)

“The TPCK framework indicates that teachers need to develop an integrated class of knowledge that will enable them to consider a multiple set of complex relationships that include such knowledge components as the affordances of the technology, pedagogical techniques that relate to the specific content area and the relationship of these technological affordances to these pedagogical approaches. It is suggested here that discussion about and knowledge of the actual school context, in these Design Study Group meetings, is a critical element in ensuring the successful implementation of technology-rich approaches.” (5311)

“that context is a frame within which knowledge of technology, pedagogy and content can be understood.” (5312)

“I believe the TPACK model is useful not just for explaining what teachers need to know, but also the order in which they decide to use that knowledge when teaching. I propose that the TPACK model, in its expression of what teachers actually do, can be better diagramed as per Figure 2. While Content, Pedagogy, and Technology are each important and sustainable educational fields, they are not dealt with by educators equally or simultaneously:
1) The educational process begins with Content: what we are going to teach takes priority. Until we have determined what will be taught, none of the other parts of the TPACK model make sense.
2) Once we have determined the subject, necessarily the particular students, goals, and environment must be considered.
3) Consistent with the arguments of Shulman (1986), Pedagogical Content – the determination of content appropriate to the given teaching situation – is next. Mishra & Koehler (2006) correctly state that Shulman’s neglect in mentioning technology was neither lack of its importance nor an intentional dismissal. When Mishra & Koehler cite Bruce & Hogan’s (1998) term “transparent,” they are explaining that technology in Shulman’s time was not rapidly changing, had little variety, and was “commonplace and not even regarded as technology” (page 1023). What I believe that Mishra & Koehler fail to take into account is that technology, while it has certainly “come to the forefront of educational discourse” (page 1023), is still the third consideration of a teacher when performing within the domain of the art. In other words, to continue the order of events, I propose that next:
4) Technology must be considered, for it is true that the instructor must understand how to use the technology, what support systems are required for its operation and maintenance, and even how to troubleshoot it when things do not go as planned.
5) Then the topic of Technological Pedagogy comes into play, for the instructor must understand how technology will related to the students, goals, and environment in place. This is true even outside of the particular content within which instructor is determined to teach.
6) Finally, the instructor must relate Technological Pedagogy with the particular content at hand. This is the TPC Knowledge, or TPACK, discussed by Koehler & Mishra (2005).
This Modified TPACK 6-step model is the theoretical foundation I will use to substantiate a use-

base typology for technology in Education. This typology occurs at Steps #5 and #6 above, where technology is evaluated in terms of the outcomes we are primarily seeking as it interacts with content and pedagogy." (Robertson, 2008, 2218-2219

"the complex interplay between technology, pedagogy, and content knowledge (TPACK)." (Schmidt, et al, 2008, 5313)

"TPACK is still defined as an emergent form of knowledge that goes beyond all three components (technology, pedagogy and content). At the intersection of these three types of knowledge, there is an intuitive understanding of teaching content with appropriate pedagogical methods and technologies. Thus, it is a framework for thinking about what knowledge teachers need to integrate technology into teaching and how they might develop this knowledge." (5314)

"The new name does much more than just buy a vowel for TPCK. We see TPACK as capturing two key aspects of our work with technology integration. First, it emphasizes, through the letters, the three kinds of knowledge (Technology, Pedagogy And Content) that we believe are essential building blocks for intelligent technology integration. Second, and as important, it captures the fact that these three knowledge domains should not be taken in isolation, but rather that they form an integrated whole, a "Total PACKage" as it were, for helping teachers take advantage of technology to improve student learning." (Thomspon & Mishra, 2007-2008, 64)

"Effective use of technology, we have learned, involves the ability to make informed decisions on how to take advantage of the affordances of technology (with a sensitivity to the concomitant constraints technologies bring to the table) to support specific pedagogies within a particular content area. Thus, teachers need the Total PACKage: the knowledge that lies at the intersection of knowledge of Content, Pedagogy And Technology i.e., TPACK. If all goes well, we will begin to see TPACK appear as our shared descriptor of the powerful ideas involved in creating a synergy among technology, content and pedagogy that honors the interdependence of these three important parts of teacher education and teaching. Emphasizing creating the total package for effective teaching and teacher education will help bring clarity and simplicity to developing knowledge of the most effective ways to help teachers take advantage of technology." (64)

"Teachers must be able to integrate technological skills and understandings with considerations about pedagogy and subject matter." (Trautmann & MaKinster, 2008, 4792)

"The size of this overlap indicates the extent to which a teacher has developed an integrated understanding of the complex relationships between subject matter understanding, pedagogical goals, and available technologies." (4792)

"Technological pedagogical content knowledge (TPCK) defines that body of knowledge that teachers now need for teaching with and about technology in their assigned subject areas and grade levels. TPCK is described as the interconnection and intersection of content, pedagogy (teaching and student learning), and technology. However, TPCK is more than a set of multiple domains of knowledge and skills that teachers need for teaching their students particular subjects at specific grade levels. TPCK is a way of thinking within these multiple domains of knowledge.” (Niess, 2008, 224)

“TPCK is a way of thinking strategically while involved in *planning, organizing, critiquing,* and *abstracting* for specific content, specific student needs, and specific classroom situations while concurrently considering the multitude of twenty-first century technologies with the potential for supporting students’ learning.” (224)

“TPCK is revealed as the knowledge, skills, and dispositions that teachers have for teaching with technology – or knowledge that includes:

- An overarching conception of what it means to teach the content with technology,
- Knowledge of instructional strategies and representation for teaching the content with technology,
- Knowledge of students’ understanding, thinking, and learning the content with technology, and
- Knowledge of curriculum and curriculum materials that integrate technology in their subject (Niess, 2005a).” (248)

“It is important to note that technological pedagogical content knowledge (TPCK) is interdependent with content, pedagogical, and technological knowledge; and also pedagogical content, technological content, and technological pedagogical content knowledge…Moreover, each and all of these are influenced by contextual factors, such as culture, socioeconomic status, and organizational structures. Thus, TPCK as it is applied in practice must draw from each of these interwoven aspects, making it a complex and highly situated educational construct.” (Harris, 2008, 255)

“Extension of the concept to ‘technological pedagogical content knowledge’ (TPCK) brings much-needed recognition of the central role of content and pedagogy in uses of educational technology – a role typically missing in discussions until recently.” (Bull, Bell, & Hammond, 2008, 273)

“To refine and articulate TPCK, collaborative work across the disciplines must be conducted with full awareness of the differing goals, inquiry processes, and habits of mind of each content area.” (283)

“TPCK can provide the conceptual frame for moving teachers toward effective and meaningful applications of technology that are directed at improving both learning and teaching.” (AACTE, 2008, 290)

“Focusing on developing curriculum and pedagogy within content areas that are rooted in TPCK will allow teachers to build the knowledge and skill necessary for them to develop meaningful learning experiences for their students that integrate technology use effectively.” (293)

“Using TPCK can shift the emphasis away from focusing upon technology itself and toward appropriate applications of technologies of all types within curriculum areas, based upon operational knowledge of the unique affordances and constraints of particular tools and resources used for learning in particular content areas." (293)

APPENDIX C

EXAMPLES OF THE CONSTRUCTS FOUND IN THE LITERATURE

Examples of TCK Found in the Literature

"Inspiration, StorySpace, HyperStudio, ClarisWorks, a web-based asynchronous communication tool, and the Internet were used during the project." (92)

"thinking about the web's applicability in education" (96)

"learned about…web authoring to construct hypertext narratives." (97)

"determine if she could actually use the technology with her students in the ways she imagined." (97-98)

"Understanding the contributions that CALL can make to the field of foreign language education" (114)

"It is fundamental for teachers to understand how CALL shapes their teaching practices. The contributions of CALL to the field of foreign language education are crucial to the understanding of TCK." (114)

"synchronous networked discussions" (114)

"the World Wide Web offers an ample spectrum of authentic materials for teachers and students." (114)

"the implementation of hypertext and hypermedia applications has proven to be of great benefit for the acquisition and retention of new vocabulary." (115)

"multimedia packages, hypermedia technologies, CALL software, and other media." (115)

"Researchers have found the use of Microsoft Word (and its editing tools) to be beneficial for both student-teacher and peer-review activities. Another example is the use of concordancing and other packages in teaching both English as a second language and modern languages." (115)

"asynchronous networks" or "telecommunication networks" (115)

"One of the best assets that teachers can have for teaching culture is access to authentic materials and environments that, in most cases, are physically far away." (115)

"TCK is involved as teachers use chat tools to present content. Thus, the use of chat tools modifies the way teachers present content to the students." (120)

"For example, consider Geometer's Sketchpad as a tool for teaching geometry. It allows students to play with shapes and form, making it easier to construct standard geometry proofs. In this regard, the software program merely emulates what was done earlier when learning geometry. However, the computer program does more than that. By allowing students to 'play' with geometrical constructions, it also changes the nature of learning geometry itself; proofs by construction are a form of representation in mathematics that was not available prior to this technology. Similar arguments can be made for a range of other software products." (1028)

"Juliet's team also grappled with questions about how to represent some of the content. For example, in her face-to-face classes, she had students physically rearrange furniture to facilitate discussions about how physical space and furniture configurations influence people's activity and interactions with one another. In order to accomplish that online, a technology expert created a module that allowed Juliet's students to view and rearrange a virtual classroom floor plan. Subsequently, Juliet planned to use it in her face-to-face classes instead of having students physically move furniture around the room. Jim noted that his challenge with the content was that the online context required extensive preplanning and frontloading of content into the web site. This was counter to his face-to-face classes where he usually had a general structure in mind for the course but he liked the freedom to make small changes from week to week based on students' needs and interests, and on his own continuing investigations into relevant literature. Mikala's challenge was figuring out how to weave software applications into the content because all of the activities required students to use a variety of computer programs to do things like literature reviews, search for web-based resources, participate in synchronous and asynchronous conversations, and create power point presentations and spreadsheets." (2211)

"For example, a response categorized as technological content knowledge would provide evidence of an understanding of how technology influenced mathematical knowledge including, but not limited to, the varied representations of a concept or procedure through technology." (5266)

"I enjoyed working with a partner and discussing different ideas and techniques of representing the math problem. I was challenging but very helpful to see two different representations of a math idea using the tutorial and sandbox." (5267)

Technology Content Knowledge
(TCK)
Using technology can fundamentally change the way people understand math concepts.

"aesthetic and practical decisions about how to lay out and "chunk" the content across the number of weeks the course would run, and looking into and experimenting with technological solutions for representing the content" (Peruski, Mishra, & Koehler, 2007, 2209-2210).

Examples of TPK Found in the Literature

“communicated as needed via email and discussion boards” (92)

“thinking about the web’s applicability in education” (96)

“she searched for ‘catacombs’ on the web and found the Vatican offered an electronic field trip through catacombs and shared that with her students.” (96)

“using the web to access information, sometimes instantaneously, offered her students the supplementary information required to understand concepts and stories they read about in class but that were not available in the school library.” (96)

“This might include an understanding that a range of tools exists for a particular task, the ability to choose a tool based on its fitness, strategies for using the tool’s affordances, and knowledge of pedagogical strategies and the ability to apply those strategies for use of technologies. This includes knowledge of tools for maintaining class records, attendance, and grading, and knowledge of generic technology-based ideas such as WebQuests, discussion boards, and chat rooms.” (1028)

“For TPK, integrating spreadsheets into teaching mathematics was new to all but Ms. S. The highest level observed during this summer was that of *adapting* where the teachers were adapting the ideas they experienced in the summer for teaching and learning mathematics with spreadsheets. Ms. S, Ms. K, Ms. J and Mr. C actively demonstrated their adaptation abilities as they designed lessons and units that they planned for teaching in the coming year. As time progressed, Ms. A grew increasingly resistant to creating lessons that integrated spreadsheets even though she initially voiced her approval for spreadsheets as useful tools for problem solving. She was labeled at the *recognizing* level rather than the *accepting* level because she was unable to complete any lessons that integrated spreadsheets. Her reluctance was based in her firm belief that students needed to initially learn the mathematics in more traditional ways and then only use spreadsheets for applications of the mathematical ideas.” (2242)

“Realizing their pedagogical goals online initially proved challenging and troublesome. All three faculty had preconceived notions about what the online context would be like. In face-to-face, you have much more feedback. The students are there and generally speaking because they’re compliant. They’ll do what you ask but those are the very things, which are going to happen online. They can choose not to do that or enter it only partially. They can do that in class too but it’s much more difficult to hold back in class because you can do things as a teacher which invites people if they’re reticent to participate (Jim, May 7, 2001). I tried to think about things that would be interesting and how to engage them and how to coerce them to do that. In a classroom, you coerce them by your social persuasion skills. In an online format, your grades are tied to this because they won’t do it unless you provide some sort of incentive to do it because there is more anonymity so I’ve tried to think that through (Juliet, May 2, 2001). Alternatively, Mikala believed that transporting her pedagogical practices to the online context was fairly simple because she relied more heavily on others to deal with the technology. I have this zone of comfort around technology that I need to know only what I need to know…. I don't want to be accountable and responsible for it. So, integrating the use of different programs as well as the important questions that (students) had to deal with was explicitly woven into every activity. I often said, 'I'd like this or this to happen. Can you make it happen' (Mikala, August 21, 2001)? Navigation through the course web site also became an important issue for all three faculty as they considered ways to engage students with the course content. Their conversations indicated that the teams were engaging more deeply with the issue of how teaching in an online environment requires finding technological solutions to pedagogical concerns. We wanted people to be able to move easily and with minimal number of clicks so that if they're deep into the problem and they wanted to go back and read the original problem again, they're one click away from that. We wanted the navigation to be sensible and intuitive (Jim, May 7, 2001). Jim and Juliet engaged directly with the technology to solve these issues, while Mikala relied mainly on her team and an external a technology expert employed by the university to assist faculty in putting their courses online. The technology expert determined how to divide the work on the pages of the web site based on Mikala's syllabus. However, Mikala still gained understanding about technological solutions to pedagogical problems by virtue of her interaction with the technology expert. The navigation part was only concrete after we saw what the (technology expert) constructed so we had no idea but the needs were stressed by (me). It was a continuous construction. We had pages available and ideas would pop up and so we went back to (the technology expert) and he constructed something else and we were adding and sharing ideas and discussing those ideas. It was a real iterative process (Mikala, August 21, 2001)." (2210-2211)

"in order to help ensure effective student learning outcomes, online pedagogy needs to address a variety of factors. These include the following:

- reducing students' reliance on text,
- exploring and valuing students' backgrounds,
- developing knowledge beyond the level of transmission,
- promoting reflective practices,
- establishing an inclusive learning environment,
- fostering communication among classmates as well as instructors,
- helping students become more self-regulated and engaged, and
- developing a group identity that connects students with their learning as well as with their social environment." (citing Brennam, 5193)"

"This project benefited me in a great way. I never had the opportunity to work with a PowerPoint in high school so have this experience was helpful. I feel that as teacher some day, knowing how to work with such technology will enhance my students' learning and educational experiences" (5267)

Technology Pedagogical
Knowledge (TPK)
I know how to use technology in collaborative learning.

"experimentation and decisions about what technologies would support their pedagogical goals"

(Peruski, Mishra, & Koehler, 2007, 2209-2210)

Examples of TPACK Found in the Literature

"Mr. Cole implements writer's workshop using technology in his fourth-grade classroom. During their scheduled writing time each day, his fourth-grade students have one-on-one access to wireless laptops in the classroom. Each student begins a new story by choosing a topic of interest based upon his/her own background experiences and knowledge. At the prewriting stage students begin to brainstorm and generate their story ideas using Inspiration. Using this software students create concept maps to visually represent their thoughts and ideas before beginning to write their story.
"Next, the students use the concept map to guide their thinking while composing the first draft of their stories using SubEthaEdit. SubEthaEdit is a text editor that allows collaborative editing so compositions can be shared online with others for the purpose of providing feedback and response. Once the first draft is complete, students participate in a recursive process that involves several exchanges back and forth between peers and/or teachers while revising, editing, and re-drafting the stories. Using SubEthaEdit, a student sends his/her draft to a peer in the classroom (or anyone in the world) who reads the piece and makes suggestions revising the document. Another unique feature of SubEthaEdit is that it is available in multiple langues like Chinese, Russian, Korean, Japanese, German, and French so communicating and collaborating with a diverse audience is possible. After students have re-drafted their writing using the suggestions offered during the revising stage, the collaborative editing process is later replicated by using SubEthaEdit during the editing stage focusing on correcting mechanics and spelling.
"Finally, after revising and editing their stories the students publish their compositions. Although publishing in writer's workshop can have multiple purposes and be done in a variety of ways, technology can still play a significant role in completing the writing process cycle. After completing edits and revisions, the students might print out their stories and then during author's chair time the students share their stories with the entire class. At times, Mr. Cole provides the opportunity for his students to publish their work online as a means to motivate them to write."(76-77)

"the preservice teachers engaged in web-based communication with each other about their experiences" (92)

"Once comfortable with StorySpace software, Nell wanted to use it to support her teaching of hypertext concepts to her students." (98)

"Nell's students participated in an interdisciplinary Slavery Project with a group of students from Ghana. The two groups of students shared in writing an African's story from his/her life in Africa, capture and deportation to America, and sale as a slave to an owner. The Ghana students collaboratively wrote four versions of the first half of the story depicting the African's life up until he/she boards a slave ship. Nell's students chose one of the four versions and completed the story to the point when the African is sold as a slave at auction. Nell's students imported the first half of the story into the Story Space software and constructed it as a hypertext narrative." (98-99)

“Though Nell believed the most effective way to communicate notions of text, writing, and reading to her students required the use of technology” (99)

“Nell felt StorySpace allowed simpler and clearer illustrations of the concepts” (99)

“Nell developed and used her TPCK to design a lesson in which her students used the technology to engage in writing nonlinear, hypertext narratives, co-authored with African students.” (100)

“For example, teaching chemistry (the content) would drive the kind sof representations to be used (symbolic representations such as equations, or visual representations such as molecular diagrams – that is, the pedagogy) and the technologies used to display and manipulate them. In this example, suitable technologies include special plug-ins, such as CHIME, that allow students to dynamically view and manipulate molecular representations. If, on the other hand, the technology currently available would not support the writing of equations or representations, it would force an online instructor to develop other ways to represent content and thus impact pedagogy. Similarly, if the course content is about learning simple facts about the properties of each of the periodic chemical elements, then some pedagogical representations (e.g., essyas) are not as attractive. Likewise, a course about film might require certain technological tools, like digital video. These interactions go both ways; deciding on a particular technological tool will offer constraints on the representations that can be developed and the course content that can be covered and delivered, which in turn affects the pedagogical process as well.” (2006, 1030)

“Adding a pressure sensor to the demonstration can allow students to replay a video of the experiment with a graph of the internal pressure superimposed beside the video. By providing synchronized multiple representations of the event, students can visualize the meaning of the graph and connect the graph to pertinent features of the phenomenon” (133)

“In contrast, ready access to primary source documents offers social studies teachers the possibility of different kinds of instructional approaches. Digital history centers and institutions such as the Smithsonian and the Library of Congress are increasingly making digital copies of historical documents such as photographs, artwork, and maps available online. These digital resources afford students the opportunity to create digital documentaries – short digital movies that contain a montage of images, text, or video accompanied by a narration done in the student’s voice. Educators believe that students who effectively use primary source documents can develop enhanced historical thinking skills.” (134)

“Evidence exists that struggling readers sometimes have difficulty forming accurate images associated with the words that they are reading. The ability to combine images with words to create digital movies offers an avenue for reinforcing visual imagery — contextualizing the text in ways not previously possible. When the words are narrated in the student’s own voice, the process may also offer opportunities for auditory reinforcement.”

“Students typically experience difficulty in understanding the relationship between a triangle and the characteristic shape of a sine wave – one has three sharp corners while the other has rounded peaks and valleys. This relationship is difficult to see in a static image in a textbook. However, when a tool such as the Geometer's Sketchpad is used to create a digital animation over time, the relationship is more easily understood. The potential is further enhanced when the possibility of interactivity is considered — that is, students manipulating the variables and seeing changes to the animation or video in realtime." (135)

Table 1
An Illustration of Linking a Technology (Digital Video) With Pedagogical Goals in Different Content Areas

Discipline	Content	Technology	Pedagogical Goals
Science	Physics	Digital Video	Rectifying Naive Conceptions
Social Studies	History	Digital Video	Supporting Historical Inquiry
Language Arts	Reading	Digital Video	Reinforcing Visual Imagery
Mathematics	Trigonometry	Digital Video	Connecting Representations

"Responses coded as TPC included reference to such issues as using technology to encourage "student discovery" and the ability to perform quick visual assessment by glancing at the computer screen which allowed for immediate feedback to the students as needed." (2183)

"When asked to identify a lesson that she liked and enjoyed working through as a student, Connie stated, "I really liked the slope lesson that we did. I really liked how it was student-centered, with the students discovering it for themselves and then tying it back to, I guess, the formal way of doing it; the y equals m x plus b." The value she places on student-centered exploration ties directly to the TPCK concept related to an awareness of the strategies that incorporate the use of technology to create a student-centered learning environment." (2183)

In the slope lesson, Connie was also impressed with the fact that the visual image made it possible for both the students and the instructor to determine quickly which students were making progress and which students required assistive feedback. During the modeled lesson, the instructor circulated the room, providing feedback if the coded cells did not indicate correct responses had been entered. In her interview Connie stated that she "really liked how when you entered an answer it either said good job or try again. I really loved that because it gives the student right on if they did it correctly or not. I also liked how it was convenient to have it pull up on all the computers and for each individual student so one student could have gotten it wrong, and instead of you checking all of them, they got immediate results at the same time." She incorporated this same visual assessment and feedback into her group's lesson. When asked in her interview, "Do you have any other things you might want to mention that might have been different about the teaching of your lesson without the technology?" Connie responded, "With technology I could visually assess whether or not they could do it." This allowed her to provide immediate assistive feedback as needed. This is confirmed in the field notes from the observation of her lesson which make note that as Connie circulated around the class she assessed what the students were creating and provided immediate feedback, reminding them that a tessellation has no gaps and no overlaps. She also indicated that "Not all shapes tessellate – keep that in mind." Without the use of the technology the quick visual assessment followed by assistive feedback would not be possible. At the conclusion of the microteaching phase of the project, a second interview was conducted and the data folder for each participant was reviewed. Upon completion of this review, several additional themes related to the development of TPCK during the MLS process emerged. Throughout the semester an emphasis was placed on teaching student-centered lessons. Connie indicates an awareness of this in her MLS feedback form when she answers the question, "What did you learn about teaching strategies while developing the lesson?" She replied: "I learned about teaching strategies: having the room student centered and using technology to aid in the learning process. The students created their own tessellations on the computer." When asked about any changes made between the first and second teaching of the lesson, Connie makes note that, "We altered the lesson to incorporate a bit more hands-on activities with technology." This confirms her awareness of the merits of using technology to promote student-centered learning." (2183-84)

"The decision to use the technology to incorporate this visual imaging option reflects an awareness of the use of a technological tool within a teaching strategy; one important aspect of TPCK." (2184)

"Kelly indicated that when making the decision for the technology to be used in their MLS lesson, her group did consider the use of Excel, but decided against it because "we were a little nervous about using it…. We weren't exactly comfortable teaching it." She expanded by adding, "Are you asking if my experiences as a student affected or influenced my decision? (Yes.) I would say so. I chose something that I knew wouldn't be too complicated for the students to do. . . I wasn't teaching about technology. I was teaching for, you know, percents proportions and circle graphs and I needed a technology resource that would help me do that. I feel like the one I chose served that purpose instead of something else." In this case, her group's lesson could have been accomplished using a spreadsheet, but her group chose a tool that would accomplish the same mathematical goal without teaching about the technology. Since the goal of TPCK is to apply technology in the teaching of content rather than teaching about technology, Kelly's group decision demonstrated the development of TPCK and its use in making pedagogical decisions." (2184-85)

"Teaching and reflecting on the MLS lesson helped to perturb Kelly's thinking about the use of calculators and her belief in mental mathematics in a way that helped her transition her thinking toward a more appropriate use of technology in a mathematical lesson, indicating development of TPCK." (2185)

"In Connie's case, the emphasis placed on visual assessment and immediate feedback indicated an awareness of the important pedagogical aspects of a technology-enhanced learning environment. Decisions such as the one made by Kelly's MLS group to move from a classroom setting to a lab setting reflected the value of the strategies that incorporate the use of technology to create a student-centered learning environment. Also, the awareness of the benefit the calculators may have afforded in Kelly's MLS group lesson indicated that she was reflecting on her decisions and reconsidering the value of including calculator technology." (2185-86)

Content	Technology	Pedagogy	Knowledge Domain
Stream Flow 1. Definition, importance 2. Process of measuring			Content Knowledge (CK)
	1. Orange, stop watch, measuring tape 2. Flow Meter		Technological Knowledge (TK)
		1. Teacher directed 2. Guided inquiry 3. Open inquiry 4. Discovery	Pedagogical Knowledge (PK)
Stream Flow Definition		Teacher directed	Pedagogical Content Knowledge (PCK)
	Flow Meter		Technological Content Knowledge (TCK)
	Flow meter	Teacher directed Guided inquiry	Technological Pedagogical Knowledge (TPK)
Stream Flow Measurement	Flow Meter	Teacher directed, guided inquiry	Technological Pedagogical Content Knowledge (TPCK)

Table 1. Components of TPCK model for teaching concept of stream flow.

"Early interviews indicated that faculty was beginning to appreciate the dynamic and complex relationship between content, pedagogy and technology (Koehler, Mishra, Hershey & Peruski, 2004). "It's not just like finding a way to get this stuff delivered. You're actually creating a new way, your instructional deliveries, you're actually creating fundamentally different ways of understanding" (Jim, May 7, 2001). Interviews during the middle and later stages of the design process indicated deeper understanding. We were thinking of the curriculum. What does it require in terms of key buttons or key navigation points or key structures? In terms of the pedagogy, what does that require? I wanted to add the lecture piece. That's a reflection of the thinking of the pedagogy. I think it's like how does the pedagogy influence the design? What if a group of people wants clarification so we want to create some avenue or opportunity to do that online (Jim, May 7, 2001)? When Juliet began the design process, she explained that she did not know much about technology and did not have much interest in learning about. However, in later interviews her explanation of her course structure, indicated new understandings about how technology helped her to achieve her pedagogical goals (individual and group learning, finding content online and in texts, providing feedback to students, etc). Each week of the class, they'll have three units, or days. First, content… they'll have to buy some texts, and online sites to visit. The second day will be small groups with applications. They'll work in chat rooms and develop a group product and post them to the whole class. Day three involves individuals looking at what they did in groups and across groups and reflecting individually to me. I'll then provide group feedback via voiceover to the whole group. In terms of how I make contact with them, every week they get an audio slide show of me previewing the week. I'm going to try to have fun with the pictures. We're going to superimpose me in different parts of the world (Juliet, September, 26, 2001). Faculty interviews during teaching show the continued progression in understanding. For example, they came to understand the importance of dedicating a "space" or a thread for each of student groups in order to more efficiently mo nitor students' small group discussions. In person, you can watch the team working and intervene. (Online) even though I was trying my best to watch the different threads, I couldn't see the progress on a daily basis. I couldn't intervene fast enough. I think that's really important in team projects, setting up these communication systems so that the instructor can see the progress on a daily or on an every other day basis and intervene immediately (Mikala, December 7, 2001). Mikala provided an example

of how all three faculty members were becoming clearer about affordances and constraints of the technology. It's almost an iterative process. When I get on line it gives me some limitations like how quickly I can write. But I found that I could do more with it as well. I had different channels of communication so… it also was somewhat liberating. How can I use all these different threads of communication to do different things? I like that a lot (Mikala, December 7, 2001)." (2211-2212)
"In our case, technology can create an environment, SimCity, for students to explore the principles, practices and decisionmaking in economics and land use planning." (2280)

"SimCity4 is a simulation of the development of a city. Users zone land, provide services, and build amenities. Through the use of tools to iteratively create, explore and develop a city, the inherent interdependability of the economics and land use planning considerations are explored and tested. The consequences of the students' actions are changes in the SimCity landscape and data representations. Based on our conceptual framework for knowledge development, we designed and implemented a continuous adaptation learning process (Fig. 2). The student develops a web of knowledge through a series of negotiations with existing knowledge, the knowledge available in SimCity and the knowledge available in the group. Students iteratively develop an understanding of city planning and balancing budgets. They apply these new understandings to their city decision making and to previous knowledge – which is continuously reevaluated and 'adapted'. The design emphasized facility with the program, the development of a robust city, the balancing of the budget, and the ability to reflect on the principles and concepts in other environments. Our students managed knowledge as a fluid and dynamic entity. Our role was as facilitator and problem solver, as discussed by Mishra and Koehler (2006). We both engaged in three types of interactions with the students. First, we answered questions on a skills based level on SimCity. Second, we asked questions of the students to support their thinking. These questions were not directive in nature, rather they were to support the students continued interaction with the complex learning environment. The third type of interaction was supportive. None of these students had participated in an open ended assignment like this and some needed reassurance that the process they were engaged in was appropriate." (2280)

"Participant's TPCK in the early stages of the research study focused more on procedural mathematical knowledge and the use of the technological tool primarily in performing arithmetic calculations. Later in the process, the emphasis was placed on conceptual knowledge and the relationship between the computations and the overall objective of the lesson. A shift in TPCK can also be seen in the specific pedagogical strategies related to the use of the technological tool, primarily in the areas of pacing and sequencing of the lessons. As the participants recognized weaknesses in these areas, modifications were made to enhance the effectiveness of the lesson. An additional shift in TPCK was evidenced in relation to the use of a technological tool in a studentcentered environment. Modifications to the lessons reflected a shift from almost no teacher-led instruction, to an integrated teacher-guided but student-centered approach. Evidence in each of these areas suggests that as the participants worked through the MLS process, their own concepts of what is involved in using a specific technological tool combined with specific technology-related teaching strategies in a manner that enhances student learning began to change, representing changes in their TPCK." (5217)

“How should a K-12 geography teacher use a geospatial technology such as Google Earth in the classroom? Should they have students pinpoint a series of locations and measure the connecting distances, essentially using the technology as a mere digital representation of the traditional globe? Or, should they encourage learners to harness the powerful data-driven affordances of the technology to make and justify decisions on contemporary issues (for example, where to build a hospital in downtown San Francisco based on factors of seismic activity and population density)? We believe it is the latter scenario. However, there is a necessary level of technological, pedagogical, and content knowledge that an instructor must develop in order to apply this scenario successfully in the classroom.” (2010)

“Consider for example a teacher education class with a mix of digital natives and immigrants. It is important to take deliberate steps in the instructional design to accommodate the needs of both groups. This could involve building technology mediated small group activities into the instruction. By design each group could include both digital natives and digital immigrants on tasks designed to motivate and facilitate the acquisition of skills by the digital immigrants while simultaneously at least minimally challenging digital natives.” (5260)

“A response that incorporated all three types of knowledge would reveal an understanding of the multiple representations of a mathematical concept using technology or how mathematical misconceptions could be overcome with technology.” (5266)

“The project was a great experience, both in terms of the valuable information I gained about the process of problem solving as well as the ability to teach problem solving procedures with the use of technology. I feel the portion of the project which benefited me the most, in preparing to create learning objects, was exploring the several approaches students take when solving a problem and being able to represent this with technology.” (5267)

“Results from the content analysis revealed that at the end of the project some preservice teachers were able to integrate their mathematics content, pedagogy, and technology knowledge into a connected structure. This structure required evidence of MKT as it relates to representing concepts using technology, finding constructive way to teach math with technology, and knowledge of how technology can address misconceptions. The content analysis also revealed that such connected knowledge was not uniformly distributed among all three types of knowledge. That is, a single response coded as TPCK did not imply that all three components are equally weighted in the response. For example, consider the response: *My favorite part of the project was creating the tutorials and sandboxes as part of the learning object for our assigned problem. This allowed each of us to use both our knowledge of the concepts we were teaching as well as our creativity, to create effective learning objects with technology.* This TPCK response depicts a more connected knowledge with mathematics and technology, than with pedagogical knowledge.” (5269-5270)

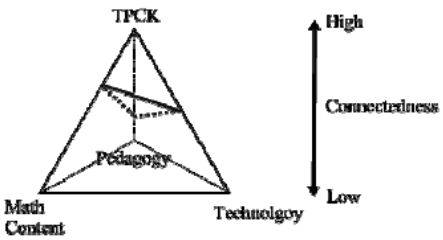

Figure 5: A Three-Dimensional TPCK Framework

"These in-depth descriptions were developed through triangulation of the data and analyzed by TPACK level resulting in the following extended descriptions that also add a sample teacher comment to illustrate the level:

1. Recognizing

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

2. Accepting

- Accepts the idea that some technologies can be useful tools for teaching and learning mathematics.
- Concerns about:

o Students' attention to and learning appropriate mathematics being diverted to a focus on the technology in the activities

o Students' thinking in mathematics when the technology is used as a tool for exploring the mathematics

o Technology classroom access and management

o The need to teach about the technology as taking away time for teaching mathematics

- Identically mimics professional development mathematics curricular ideas for incorporating the technologies.
- 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 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."

3. *Adapting*

- Recognizes some benefits of incorporating technology as a tool for teaching and learning the mathematics curriculum.
- Discusses desire to explore, experiment and practice integrating technologies as mathematics learning and teaching tools.
- Considers the technology as a tool to enhance a mathematics lesson, primarily as a means of providing students with a new way to approach the mathematics.
- Thinks of the technology as enhancing mathematics 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.
- Identically mimics the simplest professional development activities with the technologies but does attempt adapting lessons for his/her mathematics classes.
- Actions for implementing technologies in teaching mathematics 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 learning and teaching tools.
- Accepts technologies as tools for learning and teaching specific topics in the mathematics curriculum.
- Plans, implements, and reflects on teaching and learning in the implementations with concern

for guiding students in understanding mathematics using the technology as a tool.
□Recognizes challenges for teaching mathematics 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 that students are learning.
□Tentative willingness to engage students in explorations of mathematics 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.
□Manages technology-enhanced activities towards directing student engagement in learning the mathematics.
□Continues to learn and explore ideas for teaching and learning mathematics 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 firsthand 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.

5. *Advancing*

_ Sustained motivation and carry through in exploring, experimenting and practicing integrating technologies as mathematics learning and teaching tools.
_ Active, consistent acceptance of technologies as tools for learning and teaching mathematics 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 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 students are learning.
_ Engages students in high-level thinking activities (such as project-based and problem solving and decision making activities) for learning mathematics 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.
_ Manages technology-enhanced activities in ways that maintains student engagement in learning the mathematics.
_ Continues to learn and explore ideas for teaching and learning mathematics 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." (5300-5303)

Technology, Pedagogical, and Content Knowledge (TPaCK)
I will provide leadership in helping others to effectively coordinate the use of technology, pedagogy and content knowledge at my school and/or district.

"Participation in GIT Ahead has expanded teachers' TPCK by enhancing their technological literacy and helping them to integrate their new technological competencies with their pedagogical and content knowledge. The case studies illustrate examples of teachers integrating these three elements of TPCK as they design curricular applications of GIT and then implement, troubleshoot, and evaluate the effectiveness of these lessons. The case studies also provide evidence of growth in TPCK over the course of the year, with teachers reflecting on their increased technical competency and growing awareness of the curricular potential of geospatial tools. Expansion of TPCK is particularly evident when teachers begin viewing geospatial technologies as valuable pedagogical strategies rather than as new topics to be added into their curriculum. For example, case study teacher Matthew concluded that he could fit use of GPS into his highly constrained earth science classes if he treated GPS as a tool for learning about mapping rather than a topic in its own right." (4803)

emerging and crystallizing understandings about the interplay among TPCK." (Peruski, Mishra, & Koehler, 2007, 2209-2210)

APPENDIX D

SUMMARY OF THE TECHNICAL USE ANALYSIS

TCK

Definition: An understanding of the technologies that may be utilized in a given discipline and how the use of those technologies transforms the content of that discipline through representation or the generation of new content.

Essential Features: (1) the use of technology (2) in a particular content area (3) to change the representation of that content

Remaining Questions: (1) whether a pedagogical context is appropriate when considering TCK and, if so, where the "line" between TCK and TPCK is; (2) whether listing technologies used in a particular content area constitutes a level of TCK; and (3) whether or not TCK can, in fact, exist in an educational context.

TPK

Definition: an understanding of the technologies that may be used in a given pedagogical context, including the affordances and constraints of those technologies, and how those technologies influence or are influenced by the teacher's pedagogical strategies.

Essential Features: (1) the use of technology (2) as part of a pedagogical strategy (3) and how the technology and pedagogy interact

Remaining Questions: (1) whether content can/should play a role in TPK; (2) how one can distinguish between TPK and TPCK, particularly because teachers do not often separate teaching from content; and (3) whether the nature of the instructional strategy plays a role in TPK/TPCK classification.

TPCK

Definition: a way of thinking about the complex relationships between technology, pedagogy, and content in a specific context which is represented through the carefully considered implementation of technology in a classroom setting in order to help students better understand a particular topic.

Essential Features: (1) the use of technology (2) in a particular educational context (3) to teach a particular content (4) to fulfill a given educational objective/student need.

Remaining Questions: (1) whether TPCK must include the use of content-specific pedagogical strategies rather than generic ones (see the technical use analysis of TPK); (2) how much detail must be provided regarding the context in order to classify an example as TPCK (versus TCK or TPK); and (3) how to address the idea of levels in searching for examples of TPCK.

APPENDIX E

ANALYSIS OF CASES

TCK

After revising the technical use analysis and clarifying the definitions based on their distinguishing features, I defined TCK as “A knowledge of the technology-content interaction that is independent of pedagogy.” As emphasized by the interviewees, TCK cannot include a consideration of pedagogy without crossing the boundary into TPACK. Thus, a model case of TCK should exhibit a consideration of technologies that could be used for the discipline and how those technologies and the content interact outside of any pedagogical context. Some ways in which technology and content interact include the representation of content with technology, the generation of new content as a result of technology, or the transformation of technology due to the content as noted in the extended definition of TCK created in the technical use analysis.

Representation of content

Knowledge of how technology can change the representation of content seems to be the most prevalent interpretation of TCK in the literature and interviews. This type of TCK is found in the knowledge of a particular website that presents content in a new way or software that allows the manipulation of content.

Representation Example 1 – GPS. One of the most talked-about technologies in education is the global positioning system. Teachers in subjects from P.E. to science to history have created outstanding activities for their students using GPS devices. But before teachers can devise one of these activities, they must know what a GPS is and what it allows them to do with their content. Anton Ninno (2002) reveals his knowledge of how GPS helps to better represent concepts in geography. Confluence points are those spots where lines of latitude and longitude meet. The Degree Confluence Project at http://www.confluence.org provides details about nearly every confluence point throughout the world and encourages visitors to use a GPS receiver to locate a confluence point that no one has visited before and document the site. Those that visit the confluence points then upload their photos and a description of their trip to the website where anyone can view it. Ninno explains his understanding of this activity as follows:

> All over the world, people just like you are using a GPS receiver to become explorers. The object is to navigate to a point where latitude and longitude intersect as integers, meaning without fractions. We visited the confluence at 43N, 76W, and you can see the report listed under New York State. At this site, you can explore the whole planet, or visit your own neck of the woods. In all, there are more than 12,000 confluences to document, so there's plenty of opportunity get involved. Even if you don't participate, go see the beautiful photos being contributed by intrepid confluence hunters worldwide.

GPS can also be used to explore political boundaries in a similar fashion. According to Nimmo:

> "Pointers and bounders" visit spots where geopolitical boundaries meet. Think of the "Four Corners" point between Utah, Wyoming, Arizona, and New Mexico. Tri-state and other multipoint locations are your targets. Just like your confluence hunting cousins, you will take photographs and record your adventures to share on the Net.

In this example, Nimmo expresses in-depth knowledge of how GPS can be used in conjunction with geography, independent of any pedagogical context. He discusses how GPS receivers, along with digital cameras and other technologies, can be used to represent the concepts of location, latitude and longitude, and political boundaries. However, he does not talk about how GPS might be used to *teach* these concepts, thus demonstrating that his knowledge of how GPS and geography interact is independent of a pedagogical context.

Representation *Example 2 – Scientific Data Collection and Analysis*. I conducted an interview with a geology professor who had no previous exposure to the TPACK framework to determine how she uses technology in the field, in the lab, and in the classroom. Dr. Rupper described how she uses a set of technologies to collect and analyze data. When asked how she uses technology in the field, Dr. Rupper replied:

> "In the field, I use both electrical and mechanical ice core drills – so it's a drill that actually drills down into ice and pulls out plugs of ice. It's run off of solar panels, largely, with a backup generator. And right now we are in the process of working with civil engineering building an ice penetrating radar. It's low enough frequency that the U.S. it's against the law to purchase one, but you can build one. So but the radar basically images the ice beneath our feet – how deep is the glacier, are there pools of water because you would see reflections and basically you'd get back reflections are recorded at a data acquisition site. And so as you walk along the ice then you literally just make a trail across the ice and it images as you go across every few seconds. And it bounces back and records how long it takes to bounce back and you convert that to depth. So you get reflections anywhere that something would bounce back, like the radar would bounce back."

When asked why she uses technology in that way, she responded:

> "In order to get back an understanding of really the dynamics of the glacier. Glaciers flow not just because they're on the side of a mountain but also because of how thick they are. Like, so the dynamic of how fast the glacier flows versus thins and things like that is dependent on how deep the ice is, how much water's within the ice, how much water's at the bed, things like that. And then the ice core drill we use then to actually look visually at the properties of the ice that we're imaging using the radar."

Dr. Rupper demonstrates strong TCK about how the ice core drills and radar facilitate the representation of the glacier. Her understanding of the interplay between her content and the technologies is not situated in any pedagogical context. When asked how she uses technology in the lab, Dr. Rupper said:

> We take [the data we collected in the field] and you basically image the 3D version so you have single points in time as you walk across the glacier and you do several transects and then you put that together to make a 3D image from top to bottom , left to right, front to back of the area and then you can calculate volume of the ice, you can look at where the reflectors are and whether they dip, you know, north to south or how those reflections dip and things like that which gives you a sense of the structure of the ice itself. And then is the bed smooth or, you know, are there big, you know, hollowed out regions essentially and things like that that affect the flow of the ice and whether it's sliding or sticking… And I use, as well, a program that's used across many sciences called MatLab which is a software program we use for numerical modeling. So we have all this data and I wanna

> be able to say, well, if climate changed such that we warm by x amount and precipitation increases by such amount, what's the glacier gonna do? And so actual numerical modeling the ice dynamics of that glacier and trying to understand its response to changes in the climate, both past, present, and future.

Though expressed in fairly technical language, Dr. Rupper is describing the process of interpreting and representing numerical data in a new way, something that technology allows her to accomplish fairly easily in her field of study. Again, her knowledge of how she uses the technology to represent the content is independent of a pedagogical context.

Representation *Example 3 – Historical Data Analysis.* John Lee described an example found in history wherein historians use technology to analyze census data. He stated that there is a sub-field in history that analyzes numerical representations of information and that those who participate in this area of study must understand the technologies that are used for data analysis and interpretation.

> We've done work with census data, 19th century census data, in looking at a project that was in, at the University of Virginia called Valley of Shadow and the folks that developed that project – Ed Ayers and Will Thomas – who were two historians made use of a lot of census data to make arguments about the positions that people in two communities – one in the south in Virginia and one in the north in Pennsylvania – and this, the arguments that they were making through the data which required knowledge of technology, it required technology in order to do the analysis, was a piece of evidence in a larger body of evidence that drove a very important theory that we see in schools all the time represented in textbooks and in the teaching that teachers do. It's the idea that slavery was, first and foremost, the cause of the Civil War. It wasn't, and that there really wasn't anything inevitable about the Civil War as some people have suggested.

In this example, Lee demonstrates that he and others working on the project had to have a knowledge of how the technology they were using interacted with the content that they were studying. While they were aware that their conclusions might someday be used in teaching, their work with the technology had no pedagogical context and their knowledge of how to use the technology was not situated in pedagogy. Instead, the focus of their work was on how the technology they used allow them to represent and interpret the data in new ways to draw conclusions.

Additional Examples. Leatham provided the example that “a mathematician might have technology content knowledge that allows them to solve complex equations using a computer algebra system.” Grandgenett gave a similar example, citing that “I’ve even seen it in some of my classes, that somebody understands how to use a spreadsheet to do statistics or something like that, so you might know how to use Excel to look for correlations but they don’t necessarily know how to use Excel to look for correlations that help students understand relationships by kind of stepping through things.”

Other examples that emerged in the TPACK expert interviews included the knowing how use probes and digital microscopes to visualize and interpret scientific principles, how to use a reading pen – which scans and verbalizes vocabulary words - to improve one’s reading skills, and the selection of tools to solve problems in mathematics. All of these examples represent the use of technologies to represent content in some way within the given discipline, independent of any pedagogical context.

Generation of new content

Another facet of TCK is the understanding that technology can be used to generate new content in a field of study. This type of TCK requires the teacher (or scientist, or mathematician, etc.) to have a broader view of the field as a whole, reflecting on the somewhat cyclical nature of the impact of technology on a discipline.

When asked to supply a model case of TCK, Mishra provided the story of an elite physicist, Hendrik Casimir. Casimir was a theoretical physicist who also spent a large portion of his life in industry. In his book, *Haphazard Reality* (1983), Casimir reflects on what he calls

"The Science-Technology Spiral." The fundamental idea behind this spiral is that science influences technology and technology influences science. This section will demonstrate how technology influences a discipline.

Generation Example 1 - Astronomy. Casimir provides one clear example of technology inspiring the creation of new areas of study. He said, "Astronomers are particularly good at that. Hardly had the first artificial satellite been launched before they began to make plans to send measuring equipment into outer space" (p. 299). Thus, the invention of the satellite led to the creation of vast new areas of study for astronomers. A teacher with TCK would, like Casimir, understand the implications of technology on his discipline. This realization of the impact of technology on the content area is independent of pedagogy, however, meaning that the teacher can understand how satellites opened up new areas of study in astronomy without thinking about how to teach those new areas of study.

Generation Example 2 – Composition of glaciers. The interview with the geology professor cited above also revealed her understanding of how technology has impacted her study of glaciers. After discussing her knowledge of the technologies that she uses to represent content in her discipline she talked about what those technologies have done for the field, stating:

> "ice penetrating radar is something that's been used for a long time but it's something that every year is trying to be improved. As technology gets better our ability to image the ice gets better, and as well as interpret it. The nice thing about, you know, radar is that you can cover a lot of ground. Drilling a hole in ice you can only do it a couple places. And the technology of the drills have improved without megabucks. Typically you wouldn't be able to get a drill up there. Just in the last year they've developed what they consider a backpackable drill and that means six people can haul it up any glacier anywhere in the world reasonably well, set it up, drill at least 40 meters of ice sometimes a little bit more, and then haul it all back down. And so without that you just can't do that without hundreds of thousands of dollars to helicopter the equipment up and drop it off and things like that. Which means few people can do it, there's only so much money out there. And so with this new technology it means that for tens of thousands you can do

> what before took hundreds of thousands of dollars to do so it opens up a world that leaves money to take students up to do the drilling whereas before, you know, it becomes really difficult to fund their trips and stuff… And the nice thing about the portable ice core drill is that you can drill in one spot, it's pretty easy to pack it up and drill in another spot whereas before it took days if not weeks to get it set up. And then because it required huge generators and backup batteries and so forth but now that we have the technology of actually fairly light weight and reasonably priced solar panels then all you need is a very small backup generator in case you have a cloudy day or need to drill through the night, but when the solar panels are running they recharge the battery at the same time it's running the drill. It's just a really sweet setup.

This examples demonstrates Dr. Rupper's understanding of how new technologies have enabled her to study facets of glaciers that were not previously accessible. The ice penetrating radar enables her to see in, through, and under the glacier, and the backpackable version of that radar makes it possible to do those scans relatively quickly and easily. In effect, the radar has created opportunities to study new facets of geology that were not possible prior to the use of those technologies. Again, pedagogy is not a consideration in this example, rather the focus for Dr. Rupper is on the technologies that she uses with her content and how they have impacted her field.

Generation Example 3 – Saving History. Another example of how technology can generate new content in a given field is found on the blog, A History Teacher: teaching with technology in the 21st century, by Dan McDowell, a high school social studies teacher. McDowell states:

> We all have our individual memories of shared events. I have clear memories of where I was when during the Challenger disaster, the death of Kurt Cobain, 9/11, the LA Riots, Columbine, and fall of the Berlin wall. I remember being in a small Baptist Church covering a visit of Jesse Jackson, a UCSD protest that actually moved onto I5 and stopped traffic for hours, and being one of thousands of screaming fans at numerous u2 concerts over the years.

> Our individual memories might be recorded in a journal or blog. We might tell our children or grandchildren, but I can't imagine them lasting beyond a generation. One of my biggest regrets in my life so far centers around one of my grandfathers. He lived an eventful life, fighting in WWII and spending his career as a police officer in Chicago. I never asked him much about his life. When he passed 11 years ago, those memories were mostly lost to me.
>
> Technology gives us a new window to our collective memories. Holocaust survivors are telling their stories to various organizations who are recording them so that the generations to come can witness the testimonies of the witnesses. What about the rest of us? The importance of our stories has a different importance. They help define our era, interests, daily life, and culture.
>
> Well, you probably could have guessed, there is a cool newish web site that is doing just this - it is giving everyday people the opportunity to record their memories. MemoryArchive is a site powered by MediaWiki (of Wikipedia fame) where anyone can write a story about an event or individual. You simply add it to the wiki (they have instructions), they review it and then lock it so others don't change your memory.

In this example, McDowell illustrates his knowledge of the impact of this technology on history and social science, namely, that Web 2.0 technologies have taken history out of the hands of the researchers and put it in the hands of the people. Therefore, rather than simply study the accounts of academics, historians can now examine numerous primary accounts of events, making history a more living and dynamic field. Thus, the example shows McDowell's understanding of how the technology has changed the content of his field. This knowledge is independent of McDowell's understanding of how to teach history.

Generation Example 4 – New Media in Language Arts. Pope and Golub (2000), when discussing what language arts teacher candidates need to know about technology, reveal their own knowledge of the relationship between technology and language arts as follows:

> "It is critical to acknowledge the impact technology has had on our language—how we read, write, view, and visually represent information. Words used everyday such as *windows* , *files* , *menu* , and *mouse* have new meanings and mental images; headlines include such prefixes as *cyber* , *e-,* and *hyper* ; media ads and discussions include such terms as *dot com* , *url* , and *www* . Clearly, ad creators, writers, editors, and producers

> assume that members of the reading public understand this new language. These vast lexicon changes reflect not only a vocabulary shift but also a thinking shift. We have new "pictures" in our reading and listening memories, pictures which have moved into our daily communication.
>
> Besides the dynamic impact of technology on our vocabulary, technology has also brought us an expanded view of "what is considered text and how text is prepared" (National Council of Teachers of English, *Guidelines* , p. 8). The Internet, hypertext documents (like the ones in this online journal), web sites, bibliographies with url addresses, e-mail, and personal web sites (visual representations of ourselves and our work) all are different kinds of texts, different genres with their own emerging characteristics."

In this example, Pope and Golub demonstrate their knowledge of how digital technologies have irrevocably changed language arts, revealing their understanding of the relationship between technology and content and how, in this case very explicitly, technology has created new areas of study in the language arts. The emphasis of their discussion is on how technology has changed the English language in a variety of ways including how new media have introduced new genres of text. Their understanding of these changes are independent of their knowledge of how to teach language arts.

Transformation of technology

Part of TCK is also understanding that the technology-content relationship is bidirectional. While technology can affect the representation of content or even generate new content, the content can also affect technology. This was also alluded to in Casimir's science-technology spiral.

Transformation Example 1 – Scientific Advancements of Technology. Examples of the influence of science on technology are numerous, though most are found in the sciences. Casimir (1983) hints at several, as follows:

> Engineers construct electric motors and dynamos, but they only started doing this after Orsted and Ampere had discovered the force between electric currents and magnets and

> after Faraday had discovered electromagnetic induction. Maxwell predicted and Hertz discovered electromagnetic waves; it was only then that Marconi began to apply them for telecommunication purposes. Vacuum electronics was preceded by J.J. Thomson's discovery of the electron, solid-state electronics by the quantum theory of electrons in metals and semiconductors. (p. 295).

The technologies in these examples are both very specific (ice core drills) and very generic (blogs), but all examples demonstrate knowledge of the interaction between content and technology. Thus, based on the examples found in the literature and interviews, the précising definition of TCK described in the revision of the technical use analysis seem to be accurate.

TPK

The précising definition for TPK derived from the technical use analysis is: "A knowledge of the technology-pedagogy interaction independent of content or content-specific instructional strategies." Thus the essential features of this construct may be a consideration of which technologies might be used as part of generic pedagogical strategies and how the technology used would impact the pedagogy and student learning. There are a variety of these generic pedagogical strategies, including the use of technology to improve motivation, communication, visualization, classroom management, and facilitation of technology use by students.

Motivation

Motivation Example 1 – Engagement in online learning. A model case of TPK for motivation was found in Peruski, Mishra, & Koehler (2007). In this case, the teacher thinks about how to motivate students in an online environment and how that is different from motivating learning in a face-to-face classroom.

> "I tried to think about things that would be interesting and how to engage them and how to coerce them to do that. In a classroom, you coerce them by your social persuasion

> skills. In an online format, your grades are tied to this because they won't do it unless you provide some sort of incentive to do it because there is more anonymity so I've tried to think that through (Juliet, May 2, 2001)" (p. 2210).

Here the focus is on how technologies might be used to improve motivation in the online environment and how the technology used changes the pedagogical strategies the teacher would normally engage in. This discussion is independent of any content that the teacher might be sharing with the students, making it an excellent example of TPK.

Motivation Example 2 – Elementary classroom. The fifth grade teacher that was interviewed for this dissertation exhibited similar understandings. Mr. Porter is very adept at using his interactive whiteboard, document camera, video camera, and integrated sound system to teach all of the subjects in his core curriculum. When asked why he uses technology the way he does in the classroom, he responded that it helps hold the students' interest and seems to motivate them. He also noted that using the technology has changed his pedagogical strategies, helping him to interact more with the students. This example clearly shows Mr. Porter's understanding of how technology can help to motivate students in the classroom, regardless of the content that may be taught.

Motivation Example 3 – Real-world problems. Another example of TPK for motivation is of a principal in Hawaii who feels that technology helps students work on real-world problems.

> "Looking for real-world relevance has to do with students being interested in what they do, knowing that it's useful outside of school," says Kaninau. "The experiences are not contrived or in isolation, but they're a part of a larger learning activity. Without those connections, it won't be meaningful, and it'll be forgotten tomorrow" (Curtis, 2004).

In this example, the principal reveals his understanding of the role technology can play in pedagogy and student learning, regardless of content. He expresses the need for technology to be fully integrated into the curriculum and used to pursue the answers to real-world problems to make learning meaningful. These techniques are encouraged no matter what subject is being taught. This understanding of the interaction between pedagogy and technology independent of content is an excellent example of TPK.

Motivation Example 4 - Blogging. In another example, Mr. Langhorst talks about how he uses blogging to motivate his eighth-grade history students.

> "Langhorst asked each student to turn in a final project, promising to publish the best projects on the blog, and students worked extra hard for the reward of showcasing their work on this online update of the classroom bulletin board. 'If they know it's not just for me, but family members and other students can see it,' Langhorst says, 'it makes them more conscientious'" (Echlin, 2007).

Mr. Langhorst's TPK is apparent in his understanding of how the technology of blogging can motivate their students and change how they approach their work. Again, Mr. Langhorst is not talking about using the blogs to teach history, rather he is using the blog as a generic pedagogical tool to motivate his students to do their best work.

Motivation Example 5 - Wikis. Mr. Johnston takes that understanding one step further, using Wikipedia to help students see the impact of their learning.

> "'It gets old when your only audience is your teacher, for the most part,' he says. 'So, if you're publishing this work on Wikipedia and you see it edited by someone else, that creates a whole other set of issues to think about it.' Ideally, Johnston's students will see their words published, in effect, and will experience the privilege and responsibility of adding their ideas to a large, authoritative resource – kind of like being editors of a regular old hard-copy encyclopedia" (Standen, 2007).

As with the previous examples, Mr. Johnston demonstrates an understanding of wikis and how they can be used to motivate his students regardless of the content of the instruction.

Communication

Another aspect of TPK is teachers' understanding of the capabilities of technology to enhance student-student, teacher-student, and teacher-parent communication.

Communication Example 1 – Moodle Discussion Tools. Mishra and Koehler cited their example of using Moodle as a model of TPK, emphasizing that that particular tool has affordances and constraints that can be used with any content. For example, "One is called Q-and-A in which you can specify that students can't see anybody else's posts until they post something themselves. So you could throw a controversial question or ask them, you know, 'What are your thoughts on this?' and they can't…see anyone else's reply until they've posted their own thoughts on the matter." Restricting the students' ability to view others' responses until they have posted allows for different pedagogical approaches than might be possible on other discussion boards.

In this example, it is clear that Mishra and Koehler understand how Moodle can enhance the effectiveness of class discussions through certain affordances of the tool. The knowledge of these affordances and how they might impact pedagogy is independent of the content that is being discussed.

Communication Example 2 – Classroom effects of online discussion. William Bauer (2001), an assistant professor of music education at Case Western Reserve University, wrote about his use of technology to facilitate communication with and among his students.

> Electronic discussion has also provided more flexibility during face-to-face class time. While I still conduct discussions in class, I have moved several discussion activities to a Web-based bulletin board, allowing class time to be used for other projects. Several of my online discussion assignments require students to reflect on a particular topic we have covered in class. Because my courses meet for only 2-3 hours per week, only a few students have the opportunity to address a topic during classroom-based discussion. Online discussions give every student a chance to be heard. In addition, students who are not comfortable speaking out in class are more willing to express their views in a written forum that allows them time to compose their thoughts.

Regardless of the content Dr. Bauer may be teaching, he clearly understands how electronic discussion can improve communication and allow opportunities to expand the classroom. He emphasizes the power of online discussions to extend what is being learned in class and to enable him to use class time to pursue other projects. These changes to his pedagogy are a direct result of his understanding of the affordances of the technology he is using. Additionally, his knowledge of how to use the tool to teach a class does not depend on the content of that class.

Visualization

Technology can also be used as a tool to help promote the visualization or presentation of any content to students. Teachers understand that there are general strategies for presentation regardless of the content.

Visualization Example 1 – Effective PowerPoint presentations. When asked why Dr. Rupper, the geology professor, uses PowerPoint in the classroom, part of her response was:

> "I think PowerPoint also keeps me organized so that the, it forces me to make sure that the content flow and direction is, makes sense. You know, it's a logical direction the lecture's going in, you know, just little bullet points that tell students this is the most important thing on this slide, so we may talk about it for 20 minutes, but come away with A, B, and C. And trying to make it as few words as possible that just stand out. And so, yeah, I use PowerPoint a lot. But I also don't like it to overwhelm the students, cause then it's very easy just to flip through slides insanely quickly and students just, yeah, their eyes glaze over and life's over. Yeah. So, equations I typically write up on the board because I can do it step-by-step as opposed to throwing the whole thing up there all at once and then you go cross-eyed and tune me out immediately. So there's some things I still prefer to sit and write and the students can follow the flow, and then other things I really like to have the slides up there so they can see 'em."

As with Mishra and Koehler's example, Dr. Rupper demonstrates of the affordances of constraints as a pedagogical tool regardless of the content she might be showing in her lesson. In this case, Dr. Rupper uses a particular tool as part of lectures in her class because it helps her students to visualize and organize the information. These strategies are true for any content that might be presented.

Visualization Example 2 – Interactive whiteboards. Another example of TPK for visualization is Sue Holland's use of interactive whiteboards in her seventh-grade science class.

> "'I can insert links to the Internet, or go right to a streaming video on the Web,' she explains. 'During a lesson, if a student asks, "What about this?" I can say, "Let's take a look" and go online to view it, instead of just talking about it. Eighty percent of us are visual learners – I do all my lessons now as Smart Board lessons, which is cool'" (Cruickshank, 2007).

Again, Holland reveals an understanding of general pedagogy and student learning and acknowledges that the technology she has chosen changes her pedagogical strategies. Though she is a science teacher, Holland discusses the use of the technology in very general terms, implying that it could be used as she describes it with any topic or content.

Classroom Management

Technology can also be used to improve productivity and classroom management. Examples of this type of TPK include knowledge of online grading, tutoring, or document management systems.

Classroom Management Example 1 - Productivity. Mr. Porter, the fifth grade teacher, also described how he uses technology to improve personal and class productivity by posting worksheets and other assignments online, saving interactive whiteboard lessons for students who miss class, and by keeping grades and attendance online. Mr. Porter demonstrates awareness of how technology can help him to be more productive in managing certain aspects of his class that have nothing to do with particular content.

Classroom Management Example 2 – Online grading. Online grading software is quickly becoming big business as more school districts adopt programs to help their teachers be more productive. Madeline Decker talks about one such tool.

> "It's as easy to use as Grade Quick and, with the click of a button, student grades are online. Students and parents use an ID and password to access their accounts. Parents say they love it! Report card day holds no surprises!
>
> "I can post messages to my students and their parents, create seating charts, and generate more than 20 different kinds of reports, including mid-term and final grade reports for each child," Decker added. "On Fridays, all I have to do is print a missing assignments report, cut it into strips, and hand them out! Students know on a daily basis where they need to put in more effort. Grades can be weighted and entered either as letter grades, percentages, or points.

In this example, Decker expresses clear understanding of the functions of the program and how they help her on a daily basis, completely independent of content.

Facilitation of Technology Use by Students

Facilitation Example 1 – Engaging students in online research. Leatham stated that “if I know how to engage students in a meaningful search of the web where I can ask the kinds of questions that will get them to find meaningful information, to synthesize that information to be able to use it, you know, in the future, then my ability to be able to facilitate that with students” would constitute TPK. This example demonstrates how a teacher might be able to help students complete tasks on the computer independent of content. Note that the teacher is not instructing students in how to use particular technologies, rather the emphasis is on the rather generic pedagogical strategy of guiding students through a research activity for which the chosen medium is the Internet.

Facilitation Example 2 – Evaluating the purpose. A teacher with strong TPK also understands that there are times when technology use is beneficial and other times when it is not.

Brenda Dyck is one such teacher who has experienced technology use with poor results and technology use with excellent results. She discusses her knowledge of the need to constantly evaluate the purposes for using technology in the classroom.

> As a technology enthusiast, I am easily diverted by the prospects of having a class set of computers, the most up-to-date techno gizmos, cyber this, and cyber that. If my overall goal is to use technology to help students think in newer, deeper ways, I must periodically step back to re-evaluate my purpose and the depth of learning I see in the students who spend time in my wired classroom.

Ms. Dyck reveals an understanding that the use of technology is a pedagogical choice, regardless of the content being taught.

All of the TPK examples demonstrate the use of generic technologies and generic pedagogical strategies. Additionally, all exemplify teachers' knowledge of the interaction between technology and pedagogy, with particular regard for student learning. Based on these examples, the definition and essential features of TPK seem to be accurate.

TPACK

The précising definition that I created for this construct is "A knowledge of the technology-pedagogy-content interaction in a given educational context." Therefore, model cases of TPACK must include the negotiation between all three types of knowledge. Additionally, it is proposed that examples of TPACK will demonstrate teachers' understanding of subject-specific and topic-specific instructional strategies rather than generic ones.

Subject-specific

Subject-specific Example 1 – Story retelling in Language Arts. In the first example, a teacher in Hawaii has her third-grade students create animated stories. The teacher explains her reasoning for the activity thus: "'What the animation does is it assists the children in visualizing the action…The animation is a way of them developing the picture so they relate that to the writing, to what they hear, what they see, what they feel.' Technology, she adds, 'gives you one more way to teach something'" (Curtis, 2004). In this case, the teacher understands that the technology can be used as a pedagogical tool with certain content to help students better understand the content of writing. The strategy of animated stories, or story retelling, can be used with many topics within the content of language arts, but is not often used in other disciplines, thus making it a subject-specific strategy.

Subject-specific Example 2 – Inquiry learning with GPS. Inquiry learning is an instructional strategy that is used throughout the sciences that focuses on questioning, critical thinking, and problem-solving. Diane Petersen is a fourth-grade teacher who has uses GPS with her students to track horny toads in their rural community. Initially, Ms. Petersen felt that the science core she was expected to teach was "boring and shallow" and therefore decided to learn new ways to teach the content. When a visitor to the class mentioned that the horned toads that the kids often saw in the area were considered an at-risk species, Petersen decided to take the opportunity to teach her students how to think like scientists.

> Each student works with one farmer. On a given day, the farmers come to the school with the data they've collected, help students find their fields on a series of maps, and arrange their data in tables. This information tells us where, when, and how many horny toads the farmers see. Then we see if the data can answer questions: Where are the horny toads the most common? When are the horny toads most likely to be in their fields?
>
> We plot each sighting on a computer map, then put all the associated information on a large spreadsheet. From the spreadsheet, students select data to answer a question they have and use the computer to make a graph of the information. They scrutinize graphs for clarity and then write an analysis of the results, thus demonstrating a state standard -- analyzing data through graphing. This year, for the first time, we were able to overlay aerial photos of the farmers' lands onto the maps. Several farmers worked with students to plot very exact horny toad sightings.

> We also decide what information is useful and what isn't, and we design the data sheet that farmers will use to collect data for next year's class. We also talk about the value of collecting the same data year after year to capture trends. NatureMapping also finds researchers who can help us plan studies to answer new questions as we think of them (Petersen, 2005).

They create questions, gather and analyze data, draw conclusions, and even share their conclusions at national conferences. The point of these activities is not to teach students about horned toads, but to teach them, though experience, how to inquire as scientists do.

This example demonstrates Petersen's knowledge of how technology – in this case GPS and spreadsheets – can facilitate the inquiry learning process for her students. The content they are covering (horned toads) is different than it might have been had she decided to use a textbook or a WebQuest and her pedagogy is definitely different from what was prescribed in Petersen's book of lessons, but the interaction of the technology, pedagogy, and content work together to give the students an unforgettable experience with inquiry.

Subject-specific Example 3 – Cherokee County Digital Historical Project. In this example, two instructors were developed a class on local history "in an effort to construct more meaningful history experiences for students" (Clarke & Lee, 2004). Excerpts from their paper detailing the creation of the course illuminate their knowledge throughout the process.

> "To facilitate our work, we chose to create original, digital historical resources to manage and deliver some of the historical resources available through the Cherokee County Historical Association. We made a determined effort to construct these resources within the context of our emerging understanding of best practices in digital history. As a starting point, we determined that digital historical collections could take the shape of archival or interpretative resources. Digital archival historical collections typically are difficult for students to use because their designs lack pedagogical considerations. Consequently, we focused on developing an interpretative/pedagogical collection" (p. 85).

> "To demonstrate our commitment to the effective use of technology, students in the local history class focused on developing a digital version of a survey of historic properties in Cherokee County" (p. 86).

> "Students in the local history class used the survey site in small groups to develop historical questions about self-selected properties on the database" (p. 86)
>
> "For the students to answer their question, they first determined what resources they needed and where those resources were located. These are the first steps of any authentic historical inquiry" (p. 86).
>
> The project aims to demonstrate how current practices in the teaching and learning of history can be altered by applying the unique and dynamic characteristics of the Web to local historical education and research (p. 87).

This example demonstrates the teachers' understanding of how technology (digital history), content (local history), and subject-specific pedagogy (primary source research) interact to create an authentic learning context for students.

Topic-specific

Topic-specific Example 1 – Graphing with spreadsheets. Niess (2008) provides an example of TPACK in which a teacher uses interactive spreadsheets to teach graphing.

> "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 firsthand 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" (p. 5302).

In this example, the teacher had clearly considered the particular students he/she was working with as well as the content (graphing). Additionally, the teacher selected a technology to assist in representing a particular topic and reflected on how that technology changed what was covered in the lesson. The technology allowed the teacher to adapt a generic pedagogical strategy (presentation) to a topic-specific one (the use of interactive spreadsheets to teach graphing). This technology was selected for particular students in a particular context to support specific content and pedagogy, thus meeting every requirement for an example of TPACK.

Topic-specific Example 2 – Online design. In the interview, Mishra provided an example from his experience teaching the Learning Technology by Design Course. An activity that had worked well to teach particular content in their face-to-face class was not feasible for the online version, therefore Mishra had to devise a new activity that would work in the context of the online course. In his words, "So I think that was, in my mind, a good example of how something that could be done in a class face-to-face situation, you know, when you transferred the medium needed to fundamentally change everything but capture the spirit of the activity still." This example demonstrates Mishra's understanding of how the change from a classroom to an online environment, including the affordances and constraints of the technology used in that online environment, forced an adaptation of a topic-specific instructional strategy to make it work in the new class format in order to teach the basic principles of design.

Topic-specific Example 3 – Introduction to algebra. Grandgenett pointed to the example he cited in his chapter in the *Handbook* as a model case of TPACK. That example tells the story of a teacher he observed as follows:

> "She first approached the introduction of algebra by showing how it generalizes arithmetic by giving examples of specific triangles and finding their areas. This was first illustrated by having students use an electronic geoboard (an applet where virtual rubber bands are stretched on virtual pegs) available at the National Library of Virtual Manipulatives site (http://nlvm.usu.edu/en/nav/vlibrary.html). The teacher then decided to use a spreadsheet on her display device to further illustrate the area formula for a triangle by showing various examples and reinforcing the mathematical relationship between the triangle's base, height, and area, as well as identifying how algebra within the spreadsheet helped students to more efficiently compute the areas of any triangle. The teacher then further illustrated algebra in real life by having students visit various web sites and investigate several careers where algebra played a significant role. Much of the teacher's lesson was relatively spontaneous and relied on her ability to 'imagine' the next step in the instructional process. It was easy to see by the attentive looks of the students and their nodding heads that they better understood the 'power and utility' of algebra and that they were now ready to start their year of algebra study" (2008, p. 155-156).

This example is a demonstration of extremely strong TPACK, where the teacher is aware of and able to use technological representations of the content (TCK), knows how to use various technologies with her students (TPK), and is able to find the balance between the technology, content, and pedagogy to create an outstanding learning opportunity for her students. Additionally, she has created a topic-specific instructional strategy for introducing algebra to her students. Certainly not all examples will demonstrate such well-developed TPACK, but all should represent the understanding of the balance between the three factors with special consideration of students' learning.

Topic-specific Example 4 – Erosion of valleys. Dr. Rupper provided two distinct examples of how she uses technology that would be classified as TPACK. First, she talked about how she can put pictures in a PowerPoint presentation to illustrate a concept as follows:

> "So one thing that's really easy to demonstrate to students or show students is the difference between a valley eroded by a river and a valley eroded by a glacier. All that takes is a picture of a valley eroded by a river and a picture of a valley eroded by a glacier. They are drastically different – you need nothing else. The students stand there and go, "Holy cow!" You know, one is a sharp V and one is a really broad-shaped U, they're completely different. It's so drastic, that's really all you need for their eyes to pop out of their heads and go, "Oh, wow!" You know, something completely different is going on in those two different valleys, you know, and so that's something that's really simple but it just really requires point-and-click, you know take a picture and put it up next to each other and the students sit there and go, "Oh, OK. Those valleys are different," you know, and so then usually I just show them the two valleys and ask them, "What do you see?" and they're like "uhh…" you know and they describe it, "Ok, why would they be different?" you know "What formed these valleys? What cut them?" you know, and they're very quickly come to the conclusion that a river cut the V-shaped valley and then it takes them a while to figure out, ok, what would make a really broad U-shaped valley? But they eventually always come to it. You know, they sit and discuss, so… So that's a really simple one that generates a lot of discussion, you know, and starts to really pull in some of their intuitive understanding of erosional processes."

This example illustrates a simpler use of technology – pictures on a PowerPoint – that is selected to meet student needs as part of a pedagogical approach for a particular topic, thus still representing the definition and essential features of TPACK though the technology and pedagogical approach are somewhat generic. In this case, she has adapted a generic instructional strategy to make a very specific instructional activity (a topic-specific strategy) based on her previous experience teaching the topic.

Topic-specific Example 5 – Simulation of glaciers. Dr. Rupper also exemplifies more complex understanding of the affordances of technologies in the following example:

> "One really basic one that students at an introductory level don't seem to understand is, we talk, and this is specifically glaciers, but, you know we talk about glaciers advancing and retreating. Advancing makes sense to them. Retreating doesn't. I mean they understand the concept that, wait a minute, a glacier doesn't actually flow uphill, but what is a retreat? And that seems, that's actually a fairly difficult concept for a hundred or 200-level student to try to grasp what's really going on. Cause when you tell them that, well, it's melting back and the same time it's flowing forward it's really hard for them to understand that intuitively. But with a visualization or a model where they can put in numbers very simply and say ok it's snowing this much on the glacier but it's melting back at this rate, what does the glacier do? Well, I'm putting more snow on then mass I'm moving, the glacier moves forward and as they crank up the temperature they see that they can see the flow lines in the glacier that the glacier's actually moving forward but you're melting back faster than it's moving forward – that's the retreat. It's just that you're actually literally melting back the front. It's still flowing, it's just that you're melting back. Without that visualization, either in a cartoon world but preferably in a world where they can actually play with the numbers and figure out that, ok, you know, mass in, mass out, you know, if that's out of balance the glacier has to move one way or the other and they can see that all of these things are happening at once, it's just that one outweighs the other depending on what's going on in the climate."

When asked why she chose to use the simulation as opposed to lecture or a presentation, Dr. Rupper responded that:

> "It was after I failed miserably explaining the concept (laughs). The first time I tried to teach that concept every student got it wrong on the test and the ones that got it right I realized were regurgitating exactly what I said and had no real understanding of what was going on. They were able to, or smart enough I guess to memorize it and say, "I can just repeat what the professor said," but in labs and stuff I realized they had no understanding of that and so I had to figure out a way to visualize it. I can't take them out to a glacier and a glacier is slow so they wouldn't see it anyway, you know, they wouldn't see that,

> and so figuring out a way in which they could actually not just see what's going on, because that was my first step, was just show 'em, you know? I mean I can do it but if they could put numbers on it, their understanding and their ability to, if they can play with the model, if it's easy enough that they can just say "Increase precipitation, increase temperature, decrease this, decrease that" and watch what the glacier does in response, their understanding of that increases, even freshmen's increases to that of a senior level immediately because they get this incredible feel for what's important in that system and how it's moving and that it is a dynamic system. I mean, that's one of the things we always want to get across in geology is it's not static. You know, that mountain there is not just sitting there. It's a dynamic system that's constantly changing – it's being eroded down, it's being lifted up, it's changing shape, form, you know, and it's all, it's influencing the climate which then increases its erosion, changes its form – so getting this idea that things are very dynamic is very difficult to show with a static diagram, you know. So being able to use these tools, even if it's a cartoon picture…a simulation-type thing that isn't necessarily 100% reality but gives sort of the tendency of this system as you play with things I think does wonders for the students."

In this example, Dr. Rupper demonstrates an understanding of the capabilities of a very content-specific program and how it's implementation in the classroom, along with some guidance, helped her students understand what is often a very difficult concept for beginning students to grasp, constituting a topic-specific strategy for teaching glacial advance and retreat.

Topic-specific Example 6: Second Life characterization. The next example involves the use of virtual worlds to teach character development. The following recounts Ms. Medina's experience:

> "Students who are normally shy in class were less inhibited while using Second Life," she points out. "My struggling writers were actually stronger writers while using a medium they use daily to communicate with friends: the computer. My unmotivated readers liked the program so much, they invested time in reading."
>
> Medina's next project had students create avatars for characters in novels they'd read about in a unit on the American Revolution. Besides designing the look of the avatar, the students had to provide rich profile information for each one. That included a first-person description of the character's personality and role, a list of the character's interests, links to relevant Web sites, and a telling quote by or about the character, along with an explanation of why the students chose that particular quote.

> Once the avatars and their profiles were ready, the students – in character – interacted in the virtual environment with characters from at least two other novels (Weir, 2008).

Here, both Ms. Medina's knowledge of how she could use the technology in teaching generally (TPK) and how that technology might be used with the content to meet the needs of the specific students in her classroom (TPACK) are both apparent. Using her knowledge of her students, her content, the affordances of Second Life, and a more constructivist pedagogical approach, Ms. Medina was able to create a motivating educational experience for teaching this particular topic.

Topic-Similarly, Ms. Holland spoke of her understanding of the interactive whiteboard and how her students react to its use (TPK), but she also described an activity in which the different components of her TPACK are all active.

> "I just stand back, and the kids are engaged," she explains. "For example, we study diseases of the human body in seventh grade. The kids will research a disease, create a PowerPoint presentation, and then share it with the class. They can change their presentation while standing at the board, or write on the board if someone asks a question" (Cruickshank, 2007).

In this example, it is apparent that her pedagogical strategies have changed with the introduction of the interactive white board. Additionally, the students' learning of a particular content is paramount and the technology is used as a tool to help them grasp that content and represent it in new ways.

> Another example is set in an eighth-grade history class. For the final class project, "[Mr.] Langhorst offered traditional options such as 'Write an alternate ending for the story,' but he gave students the chance to exploit new technologies as well. For instance, students could record an 'interview' with one of the book characters, using Audacity, a free audio-editing software program. 'New technology allows kids to create something with what they've learned, which is one of the highest levels of Bloom's taxonomy of learning,' he says" (Echlin, 2007).

Again, the teacher's understanding of technology, content, pedagogy, and student learning are apparent. He is not only aware of which technologies might be used and how to implement them in the classroom, but he is also aware of the effects those technologies will have on student learning – helping them reach a higher level of cognitive processing.

A final example illustrates the idea that technology can be both the content and the means of teaching that content.

> "Take, for example, 'Web 2.0,'" [Ms. Davis] says. "I take six new terms having to do with 'Web 2.0' and create a page in the wiki for each term. I give the students a template and say, 'This is a structure of what I want you to find. Find examples, write reviews.' Then I pair them up, and they complete the wiki forms in groups. They have to ask themselves, 'What do I not know about this topic?' So they formulate their questions and go on the Internet – no copy and pasting allowed – and every source is hyperlinked" (Standen, 2007).

Ms. Davis is aware of and can use wikis, contemplates her students' current level of understanding of this particular content (in this case, technology itself), and implements the wikis as a pedagogical tool to teach that content. The examples for TPACK demonstrate both specific technologies (glacial simulations) and generic ones (wikis). They also include a variety of instructional strategies. All of the examples show teachers' knowledge of the interaction between technology, pedagogy, and content, though with varying levels of complexity. Thus, based on the examples from the literature and interviews, the revised definition and essential features from the technical use analysis appear to be accurate.

Contrary and Related Cases

While the model cases help to illustrate each of the constructs individually, a comparison of the cases across constructs should help to illuminate and refine the boundaries between the constructs. Using the concrete examples provided by Dr. Rupper should provide the richest opportunity for comparison as each of those examples has quite a bit of detail and is an authentic instance of technology use. Additionally, some of the examples from the TCK construct and Edutopia.org provide an opportunity to contrast one construct with another, again using concrete examples.

Looking at the TPACK diagram provided by Koehler and Mishra, it is tempting to assume that the difference between TCK and TPACK is simply the addition of pedagogy or that the difference between TPK and TPACK is just the addition of content. However, all of the TPACK experts interviewed agreed that the distinction between constructs is more than simply putting technology in a classroom context or adding content to existing TPK. Comparing these examples should help to explain that distinction.

TCK and TPK

In Dr. Rupper's examples of TCK, she used technology in the field and laboratory to better understand and represent the composition of glaciers. The technologies that she used were largely specific to her field of study (ice core drills, radar, MatLab) and their use was focused on representing particular geology concepts. These examples demonstrate Dr. Rupper's knowledge of the interaction between her content (glacial geology) and technology. In contrast, Dr. Rupper's example of TPK involved an understanding of why she uses PowerPoint in her classroom lectures, including how the program keeps her organized and helps her students focus on the most important topics as she presents information. This example shows her knowledge of the interaction between technology and pedagogy.

Additionally, Dan McDowell talks about how blogging can change how we record and remember history, demonstrating his knowledge of the way technology can transform content. Meanwhile, Mr. Langhorst discussed how he uses blogs to motivate his students to do a good job on their class projects, showing his knowledge of the relationship between pedagogy – particularly student motivation – and technology use.

Contrasting these examples results in a few conclusions about the distinctions between TCK and TPK. First, while TCK can include either content-specific or generic technologies, TPK seems to only includes generic technologies. Second, and perhaps most obviously, TCK focuses on content without pedagogy while TPK centers on pedagogy without content. But in addition to pedagogy, there also seems to be an awareness of the needs of the students and how the technology can help them learn, regardless of the content.

TCK and TPACK

Again, in Dr. Rupper's examples of TCK, she demonstrated knowledge of the use of specific technologies in her field to better understand and analyze geologic principles. In her examples of TPACK, she found ways to represent the content to her students. At times, that included using the technologies she used in the field while at other times it meant using graphics, presentation software, or simulations. The choice of technology depended on the needs of her students, the nature of the content being taught, and previous experience in teaching those topics.

In contrast with Mr. McDowell's understanding of how blogging is changing history, Ms. Medina teaches her students about character development by having them create avatars in Second Life. This activity provides students the opportunity to decide the characteristics and personalities of their characters and to describe how those characters interact with others. Ms. Medina is balancing her knowledge of the technology (virtual worlds), content (character development), pedagogy (discovery learning), and her students as frequent users of virtual worlds to create an activity that is engaging and enlightening.

As was emphasized by the TPACK experts in their interviews, the distinction between TCK and TPACK is more than simply placing TCK in an educational context. Both of these examples show that, in addition to a teaching context, the teachers had knowledge of how to teach the content with the technologies as well as an understanding of their students' needs and interests.

TPK and TPACK

The distinction between TPK and TPACK is most easily seen in descriptions of the same teacher's knowledge using the same technology with slightly different perspectives. For example, Dr. Rupper knows that PowerPoint helps her to stay more organized during her lectures, allows students to learn content visually, and helps them focus on the main ideas (TPK). Because she understands the affordances of PowerPoint, Dr. Rupper is able to use the tool to represent particular content that she knows is difficult for her students to understand, using images of V- and U-shaped valleys on the slides so that students can engage in direct comparison and discussion (TPACK).

Ms. Holland provides another excellent contrast. She has knowledge of the affordances of the interactive whiteboard in her class, including the ability to link to the Internet, show streaming video, and utilize the included lesson plans (TPK). Ms. Holland is able to then use that knowledge to create activities in which her students use the Internet to perform research on diseases, create a presentation, and use the interactive whiteboard to teach each other. This activity demonstrates Ms. Holland's knowledge of technology (Internet, PowerPoint, and the interactive whiteboard), content (human diseases), pedagogy (student inquiry and peer teaching), and her students (engaging learners).

While the main distinction between TPK and TPACK is the introduction of content, these examples and the TPACK expert interviews reveal that plugging content into the technology is not sufficient – at least not for strong, or model, TPACK. A teacher with strong TPACK will select appropriate technologies to represent the content in a way his students will understand and which will work with his pedagogical strategies and goals.

Borderline Cases

The next step in the conceptual analysis was to test the definitions and essential features of each of the constructs by finding borderline cases and checking to see if the researcher and others could utilize the definitions and essential features to classify the cases reliably.

The first borderline case chosen by the researcher is Koehler and Mishra's example of Geometer's Sketchpad as it has already proven to be somewhat confusing. The text of the example follows:

> For example, consider Geometer's Sketchpad as a tool for teaching geometry. It allows students to play with shapes and form, making it easier to construct standard geometry proofs. (p. 1028)

The initial thoughts of the researcher on this example are that it actually does not fit into the TPACK framework at all. This example does not say anything about a teacher's *knowledge*, and this framework is professed to be a model of teacher knowledge. Were the example reworded to explain what the teacher knows about Geometer's Sketchpad, it might fit into the model. For example, "Mrs. Hanks likes that Geometer's Sketchpad allows her to visualize 3D shapes" would be classified as TCK, while "Mrs. Hanks considers how Geometer's Sketchpad could be used in her lesson to help her students better understand 3D shapes" would be an example of TPACK.

The remaining borderline cases will be first-person accounts, providing better insight into the teacher's knowledge. Example #1:

> Emma Haygood, a science and technology instructor at Berrien Springs Middle School, in Berrien Springs, Michigan, says Discovery Education Science levels the playing field for students, giving everyone an opportunity -- and an enticement -- to learn. "We don't have a lot of money for materials and supplies," she says. "The service offers a lot of interactive labs the kids can work on that I wouldn't otherwise be able to have in my classroom. And because it's on the computer, makes noise, and is interactive, they think it's the greatest thing" (Smart, 2008).

This case is considered borderline because, while the site is used for a specific subject area, the teacher's understanding of its use as part of her pedagogy seems quite general. Because student learning is considered, it is more than TCK, and the generic nature of her comments seems more like TPK except for the fact that the site is used for a specific content.

Example #2 :

> "The board is very useful to demonstrate and teach editing and rewriting," says Parker, who works in an inner city school with many bilingual students. "There are pens in different colors that allow you to write directly into the Word document you're using and save the editing marks, which is extremely helpful."
>
> One of the board's benefits, Parker adds, is that all students can easily see the images, enabling the lesson to become an engaging group activity. "Instead of crowding around little monitors, the students take turns interacting with the computer," she says. "They also get support from each other. The teacher can use it to demonstrate, then the students can use it to practice, but without feeling like they're put on the spot." Parker uses the interactive whiteboard in class daily, often in conjunction with the Internet, she adds, "in all subjects: reading, literacy, math, writing, science, geography, and social studies" (Cruickshank, 2007b).

This example seems to be TPACK in the first paragraph, save that she is not directly discussing the needs of her particular students. But from the second paragraph it seems that she may be pulling from her TPK to come up with an example of how she can use the board to teach that one content, regardless of the context.

Example #3:

> When I was working on my master's degree in education at New York University, I was placed at a school in the Bronx and looking for ways to engage the students. I had my laptop with me, which already had some music-production software I had loaded myself -- early versions of FL Studio, Acid, and Sound Porch. When I let the students use it, they took to it immediately, like a magnet to iron. I've found that the kids, who are real digital natives, pick it up quickly -- especially because the software's so intuitive. That first time using it, I realized the software had a place in schools and was an excellent way to teach music and technology (Crawford, 2007).

This is a case in which the students' use of a software inspires the teacher to use "software" to teach music and technology. Is this basic awareness part of the TPACK framework or not quite yet? Would it be considered TPK because it is, as yet, a somewhat vague idea that technology might be used? But he does mention a particular content – music. It seems to be more than TCK because he specifically mentions teaching. But is it TPACK? There does not yet seem to be consideration of particular students or context.

Example #4:

> The user doesn't need specific training in an instrument, or any understanding of standard notation or music theory. Basically, the software serves as a virtual orchestra so students have at their disposal a whole array of sounds to work with, translating music into a visual language and creating a grid pattern that allows them to see the music and get rhythms and melodies going. In no time, they'll be making sounds. Whether or not it's always music, I guess, is open to interpretation (Crawford, 2007).

This seems to be more a discussion of the affordances of the technology (TCK) than of how it interacts with pedagogical strategies, though students are mentioned.

Example #5

> "We go to places like Mount St. Helens, so we can see the devastation there," says King, somewhat breathlessly. "We go to the Grand Canyon. We fly over the San Andreas Fault, and you can actually see the fault line. Anything we're learning about, we'll just fly there!"

Is this TPK in that she knows how she can use Google Earth to teach in general, or is it TPACK because she knows how she can use Google Earth with specific content? In this case, the teacher is not specific about a context or particular students, but does mention some specific topics of study.

Example #6

One example, while told in third person rather than first, that has caused the researcher some difficulty is found in the *Handbook* chapter by Hughes and Scharber. It is the story of Laura, a new teacher who has learned to use the Internet in various ways to support her teaching.

> With Laura's immediate access to the web at her teaching station (affordance), she began using the web in her daily teaching, as demanded by students questions. For example, while reading Edgar Allan Poe's "The Cask of Amontillado," she found students had difficulty understanding the story. She thought having a better image of the story's setting might help them. In the moment, she searched for "catacombs" on the web and found the Vatican offered an electronic field trip through catacombs and shared that with her students (technological pedagogical knowledge). In another instance, Laura used the web as a learning resource for herself. She had difficulty explaining the Cold War to her students – as background for a story they read. After school, she found resources on the web to educate herself, so she could explain the concepts to the students adequately (content knowledge). Laura found that using the web to access information, sometimes instantaneously, offered her students the supplementary information required to understand concepts and stories they read about in class but that were not available in the school library (technological pedagogical knowledge) (p. 96).

In particular, the example of Laura's search for "catacombs" seems to go beyond TPK as the teacher is using the technology as part of her pedagogy to fulfill a student need in the classroom.

Invented Cases

The final step of the conceptual analysis is to invent cases that can be classified according to the TPACK framework as a final affirmation of the definition and essential features. The researcher invented four examples using the same teacher and technologies to demonstrate the features of each of the constructs that have been discussed – TCK, TPK, and TPACK – as well as technological knowledge (TK). The TK example was included to emphasize the distinction between TK and the other constructs in the framework.

> TK: A high school world history teacher hears about a technology called a *weblog* and learns how to create one.
>
> TPK: The teacher thinks about how he could use weblogs with his students. He could keep one for his classes with assignments, calendars, and other classroom management items. He could also have his students keep their own blogs to improve their writing and reflection.
>
> TCK: The teacher reflects on how weblogs could impact history. He realizes that, if a lot of people keep weblogs, we could have numerous first-hand accounts of events, taking history out of the academic ivory tower and putting it in the voices of the individuals who lived it. He searches the Internet for weblogs by people in Israel, Iraq, China, New Orleans, and other places that are of current importance and sees how powerful weblogs can be.
>
> TPACK: The teacher decides to use weblogs to help his students understand that history is happening all around them and to help them see their place in it. They begin by reading a historian's account of an event, then a first person account of the same event. They talk about the difference in impact of the two. Then they search the Internet for weblogs written by students their age in other parts of the world that are currently playing a large role in world affairs. The students then create their own weblogs which they use to write about what's going on in the world around them, including direct links to and reflections about what the students whose blogs they are reading are going through.

These examples clearly demonstrate the distinctions between each of the constructs, from simply knowing how to use the technology (TK) to knowing how the technology interacts with a particular content (TCK) to knowing how to use the technology to teach (TPK) to knowing how the technology might interact with the pedagogy and content in a particular context to meet student needs (TPACK).