Diagramming TPACK in Practice:

Using an Elaborated Model of the TPACK Framework to Analyze and Depict Teacher Knowledge

By Suzy Cox and Charles R. Graham

The introduction of the TPACK model by Mishra and Koehler (2006) has had a profound impact on the field of educational technology. It has inspired teachers, teacher educators, and educational technologists to reevaluate their knowledge and use of technology in the classroom. While Koehler, Mishra, and others have attempted to define and measure TPACK, the framework is not yet fully understood (Angeli & Valanides, 2009). Thus far, the explanations of technological pedagogical content knowledge and its associated constructs that have been provided are not clear enough for researchers to agree on what is and is not an example of each construct. Mishra and Koehler and others have provided definitions of TCK, TPK, and TPACK that articulate to some degree the centers of these constructs, however the boundaries between them are still quite fuzzy, thus making it difficult to categorize borderline cases. In order to help clarify these boundaries and facilitate study of TPACK in practice, this paper presents the key findings from a conceptual analysis of the TPACK framework.

Method

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). In this study, the objective was to create a precising definition—one which draws from typical usage of the term and to clarify the meaning of that term (Copi & Cohen, 1990)—for each of the TPACK constructs. 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, we reviewed our definitions and conclusions with TPACK experts and tested the definitions through examples (Beardsley, 1966).

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 research context, we chose to implement five techniques: 1) technical use analysis, 2) model cases, 3) contrary and related cases, 4) borderline cases, and 5) invented cases.

Technical use analysis involves reviewing existing definitions of the concept under investigation to determine how it is currently being used. Model cases are examples that possess all of the essential features of the concept. Contrary and related cases are examples of opposite or somewhat different constructs that can be compared with the model cases to better define the boundaries of a concept. Borderline cases are examples that cannot clearly be classified as belonging to one concept or another without further defining the concept. Finally, invented cases are examples created by the investigator to test the concept definition.

The technical use analysis technique was chosen because it is useful for helping to understand how others have defined and utilized an existing concept (Soltis, 1978). The remaining techniques were selected because they are the most widely accepted methods in conceptual analysis and are used to elaborate the essential features of and boundaries between concepts (Wilson, 1963). The combination of the technical use analysis and case techniques allowed us to define and clarify each of the associated constructs within the TPACK framework.

Conceptual analysis is a cumulative methodology in which each step builds on and impacts the step before it. Thus, it is not easy to reduce a description of the process we followed for this study to a few pages. Our procedure included the following steps (Cox, 2008):

1. A review of definitions of TCK, TPK, and TPACK found in the literature to create initial definitions for each construct
2. Interviews with seven TPACK researchers to clarify discrepancies, answer questions, and define examples of the constructs
3. Revision of the initial definitions to incorporate information from the interviews
4. Search for model cases in the literature and online as well as interviews with teachers that exhibit the essential features of the constructs as determined through the technical use analysis and interviews
5. Comparison of model cases across constructs to define essential features and clarify boundaries
6. Revision of definitions to make the essential features and boundaries more explicit
7. Testing the definitions through cases, both real and invented
8. Finalization of the definitions and creation of a graphic organizer
9. Utilization of the definitions and graphic representations to analyze cases

The result of this conceptual analysis is an elaborated model of the TPACK framework that elucidates the essential features and boundaries between each of the constructs. This elaborated model was informed by Koehler and Mishra's extensive work on TPACK, numerous articles about the TPACK framework from the last several years (Koehler & Mishra, 2005, 2008; Koehler, Mishra, & Yahya, 2007; Mishra & Koehler, 2006), and an analysis of pedagogical content knowledge in science by Magnusson, Krajcik, and Borko (1999). We used Magnusson, Krajcik, and Borko (1999) as a way of thinking about PCK because they have done a particularly thorough job of concretely describing the distinctions between PK, PCK, and CK.

"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."

In their analysis, Magnusson, Krajcik, and Borko (1999) 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" (Magnusson et al., 1999, 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" (Magnusson et al., 1999, 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. For example, a biology teacher might use a PowerPoint presentation with side-by-side graphics to compare living and non-living things.

Topic-specific representations include illustrations, examples, models, analogies, etc. These representations are concrete manifestations of a concept within a given subject area. For ex-

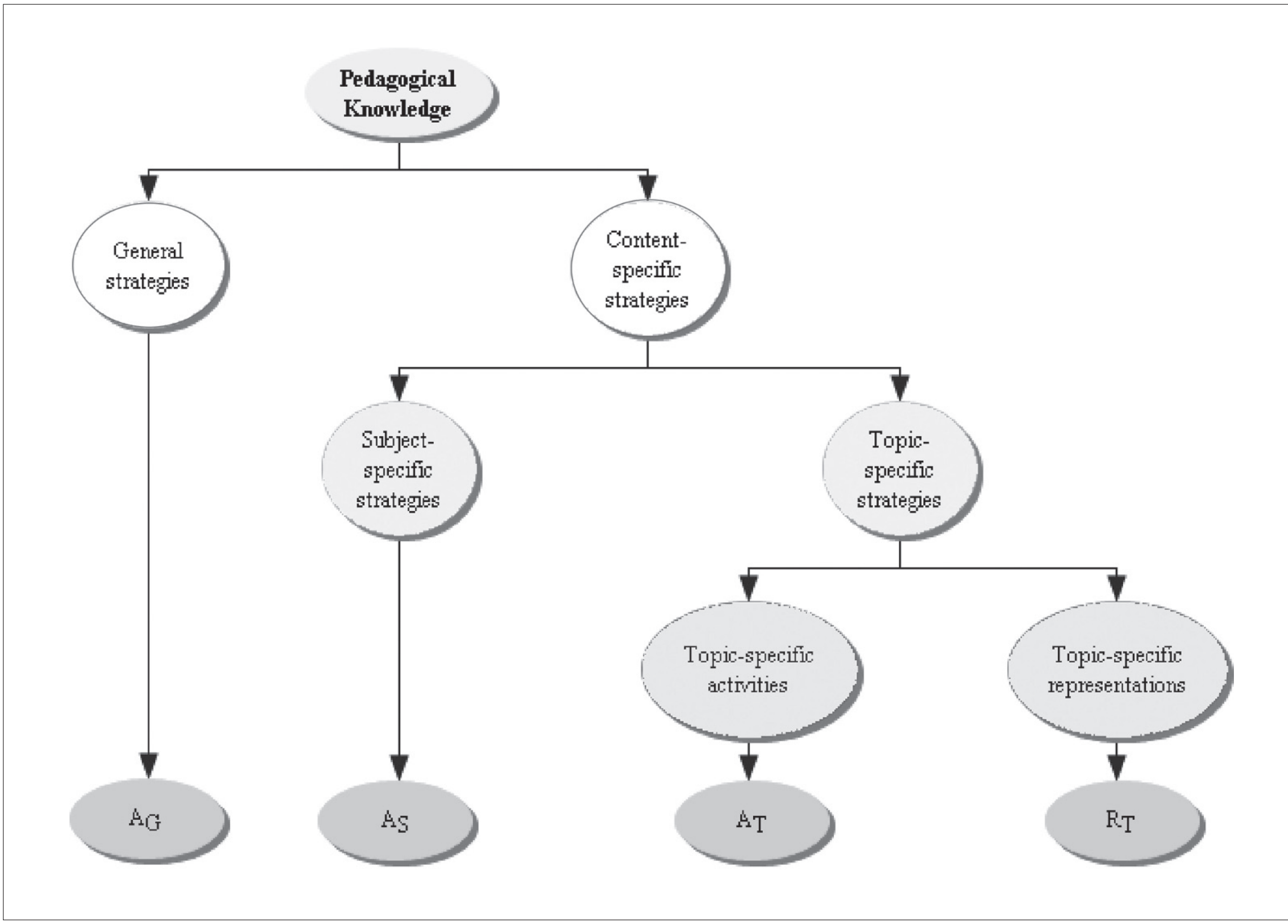

Figure 1. Pedagogical Knowledge informed by Magnusson, Krajcik, and Borko (1999)

ample, an earth science teacher might use the University of Nebraska-Lincoln's simulation to demonstrate the phases of the moon (*http://astro.unl.edu/naap/lps/animations/lps.swf*).

The addition of general strategies, as shown in Figure 1, makes the analysis by Magnusson, Krajcik, and Borko a good fit for clarifying the constructs in the TPACK framework.

Results

The conceptual analysis resulted in two definitions for each construct of the TPACK framework: an expansive definition that demonstrates the breadth and complexity of each construct as derived from the technical use analysis and review of cases and a precising definition that highlights the unique features of each construct (Cox, 2008). We have included only the precising definitions here in order to focus on the utility of this elaborated model for classifying cases. Figure 2 is the graphic organizer that resulted from the conceptual analysis and will provide context for the definitions that follow.

Pedagogical Knowledge (PK)

In the elaborated TPACK framework proposed 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 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 than some may be comfortable with, examining pedagogy in this way helps to illuminate the differences between the TPACK constructs.

Referring to general pedagogical knowledge as being independent of content is somewhat misleading in that one cannot teach anything.

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 unique activities for each topic.

Content Knowledge (CK)

In this framework, content knowledge is simplified to indicate a knowledge of the possible topic-specific representations (R_T in Figure 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 as conceived by Shulman (1986, 1987) has been researched extensively. However, there are many different conceptions or models of what kind of knowledge is part of PCK, which has made the construct difficult to research (Marks, 1990). Van Driel, Verloop, and Vos (1998) compare five of the prominent models of PCK and an understanding of strategies and representations are represented in four of five. Pedagogical content knowledge combines knowledge of activities (or strategies) 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 2) can be used across topics in a given discipline. For example, a social science teacher might use primary source documents to teach about the American Civil War or the American Revolution. Topic-specific activities (A_T in Figure 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 (1999, 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.

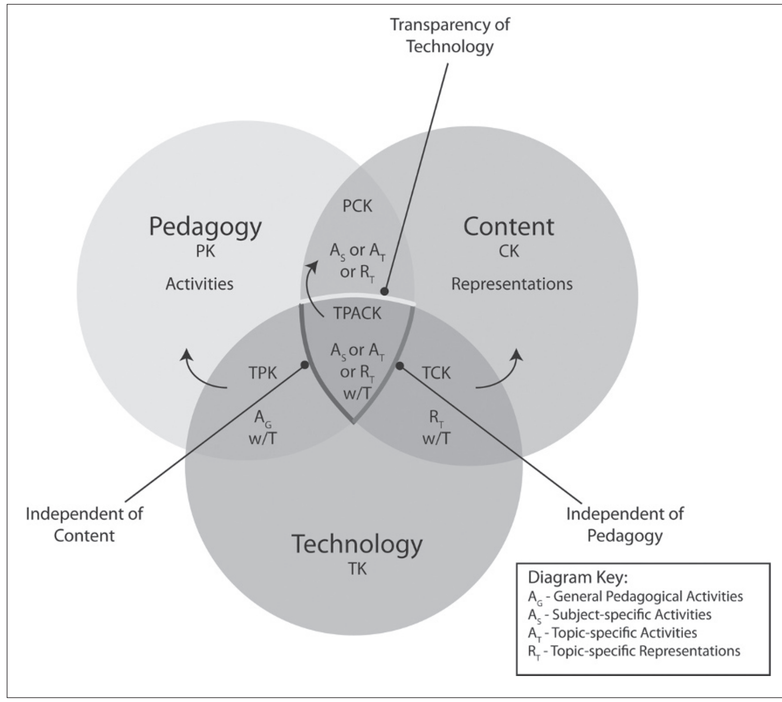

Figure 2. An elaborated model of the TPACK framework (Cox, 2008, p. 74).

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. Books were not widely accepted and utilized right away, but after several hundred years, they are now so ubiquitous that no one thinks of them as a technology. The sliding nature of technology in the TPACK framework is demonstrated by the arrows in Figure 2 and will be discussed in more detail with each of the remaining constructs.

Technological Content Knowledge (TCK)

In the elaborated model of TPACK that we 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 we 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)

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)

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 we 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.

Case Studies

The following cases illustrate each of the constructs and how the model serves to differentiate between them. They also introduce a new way of diagramming TPACK cases, using graphic representations to classify and understand a teacher's knowledge.

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 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 the equation 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 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 3. 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.

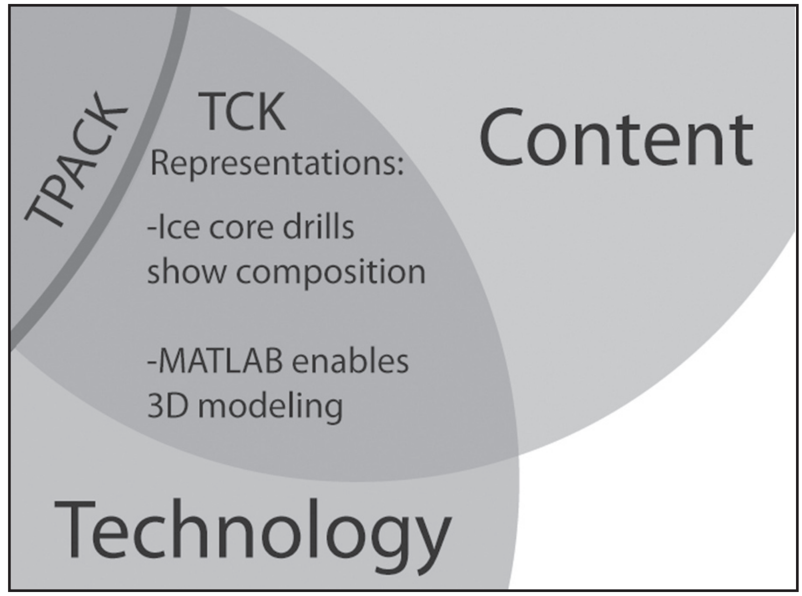

Figure 3. Dr. Rupper's knowledge of content-specific representations.

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.

TPK. Dr. Rupper's knowledge of general pedagogical activities utilizing technology constitutes her TPK, as shown in Figure 4 on the next page. 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.

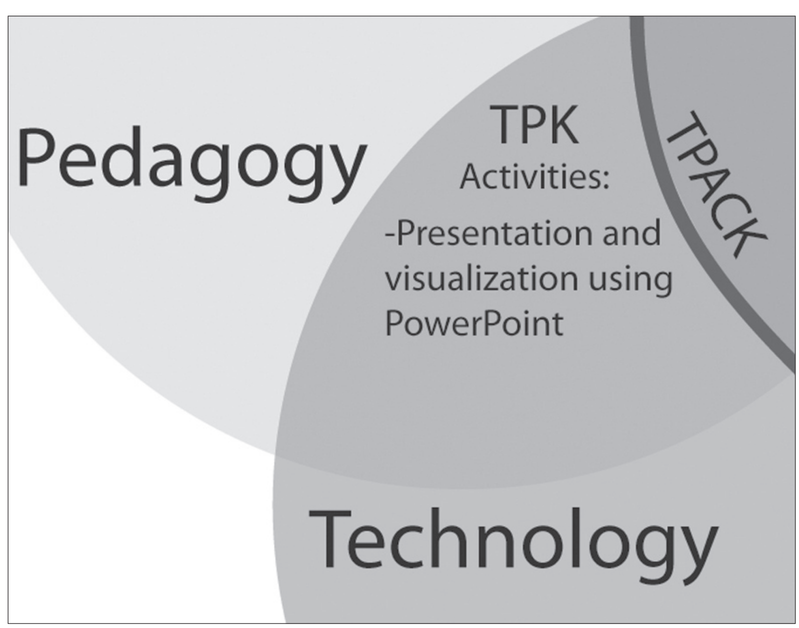

Figure 4. Dr. Rupper's knowledge of general pedagogical activities.

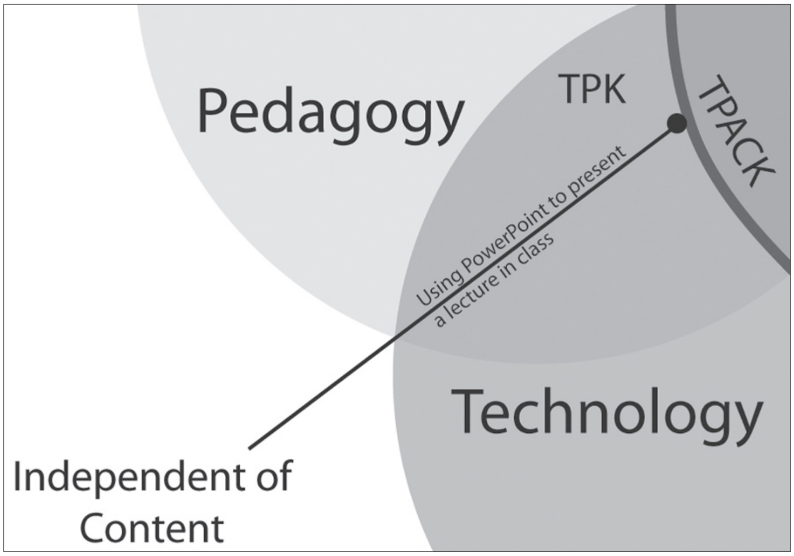

Figure 5. An example of Dr. Rupper's borderline TPK.

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.

Knowledge of PowerPoint in a presentation activity might also be considered a borderline example (see Figure 5) 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.

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 6.

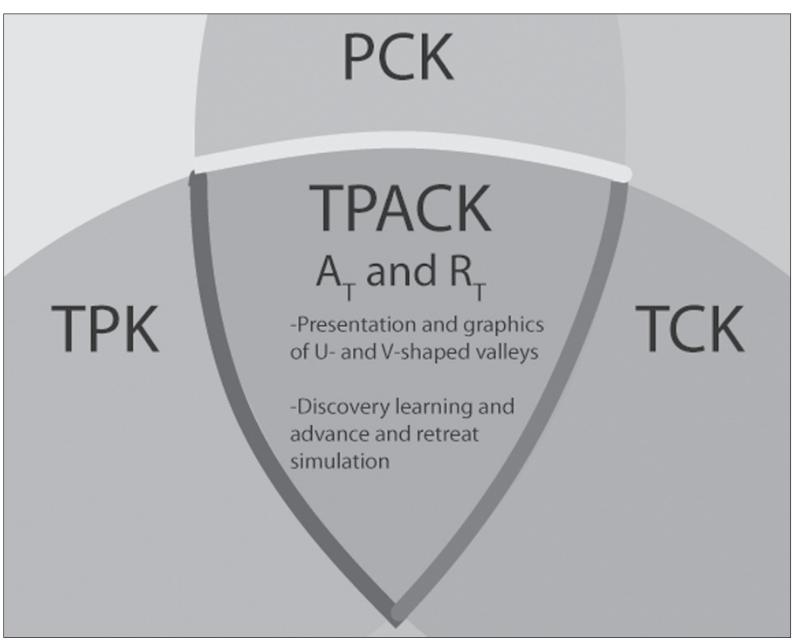

Figure 6. Dr. Rupper's knowledge of content-specific activities and representations.

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 history and 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 7).

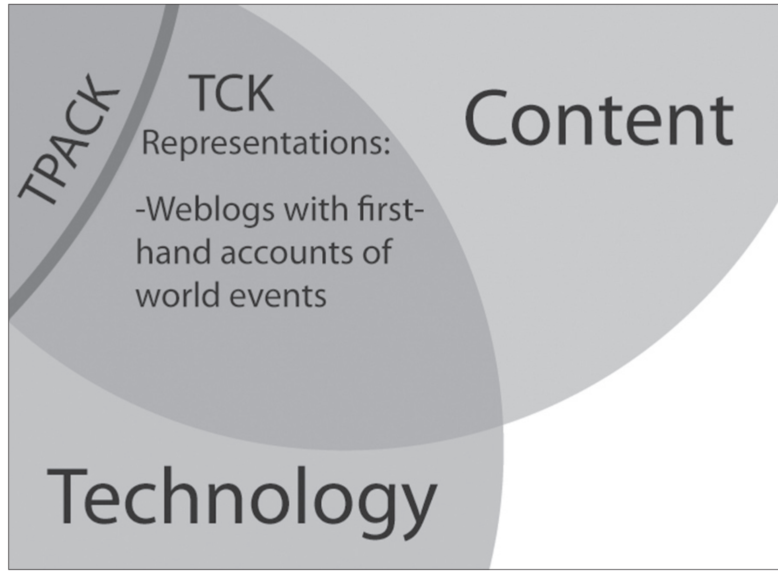

Figure 7. Mr. Jorgensen's knowledge of content-specific representations.

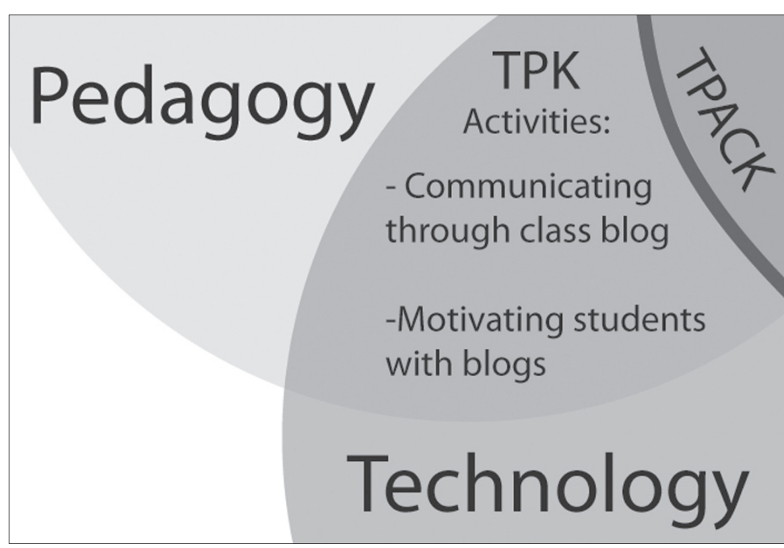

Figure 8. Mr. Jorgensen's knowledge of general pedagogical activities.

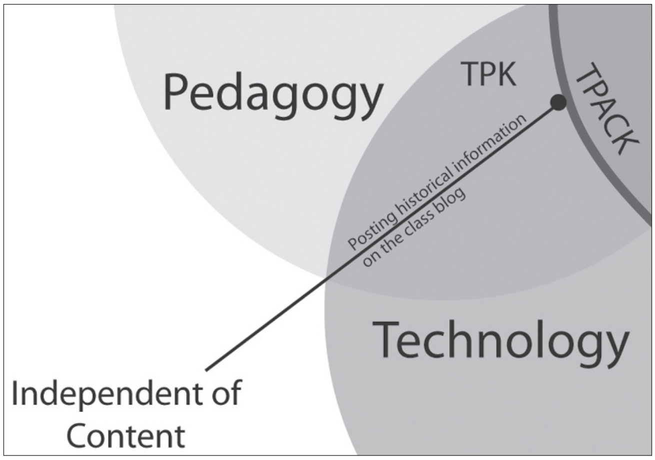

Figure 9. An example of Mr. Jorgensen's borderline TPK.

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 8.

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 9. Mr. Jorgensen's focus in this case is on the activity of communication rather than on topic-specific representations using the blog.

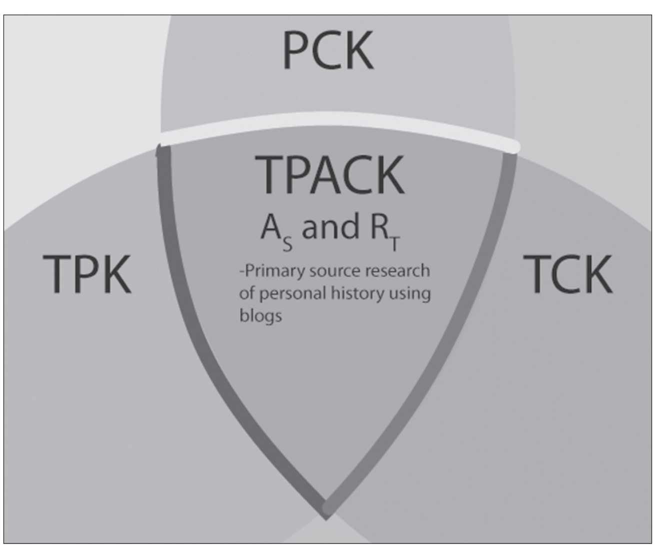

Figure 10. Mr. Jorgensen's knowledge of content-specific activities and representations.

TPACK. Mr. Jorgensen's knowledge of the use of blogging in support of content-specific activities and representations constitutes his TPACK (see Figure 10).

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.

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.

These cases serve three purposes. First, they provide support for the elaborated TPACK model that we 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.

Conclusion and Suggestions for Future Research

This conceptual analysis has enabled us to clarify the definitions of and boundaries between the TPACK constructs, allowing TPACK researchers to discuss the constructs using common and more precise vocabulary. In particular, the focus on generic versus content-specific pedagogical strategies is particularly useful for differentiating between TPK and TPACK. Additionally, our proposition that TPACK is a "sliding" framework based on emerging technologies contributes to the ongoing dialogue regarding the definition of technology. Finally, the graphic representations of TPACK cases introduced here will facilitate classification and discussion of future examples.

While we 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, we feel that it would be

extraordinarily important to use these new definitions and the elaborated 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. Cox (2008) implies 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 teacher educators 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 we 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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