Teachers' Technological Pedagogical Content Knowledge: Curriculum-based Technology Integration Reframed

Judith B. Harris (judi.harris@wm.edu)
College of William and Mary

Punya Mishra (punya@msu.edu)
Matthew J. Koehler (mkoehler@msu.edu)
Michigan State University

Abstract

In this paper, we critically analyze extant approaches to technology integration, arguing that current methods are technocentric, often omitting sufficient consideration of the dynamic and complex relationships among content, technology and pedagogy. We recommend using the Technological Pedagogical Content Knowledge (TPCK) framework as a means for thinking about how integrated conceptualizations of technology, pedagogy, and content as interdependent aspects of teachers' knowledge would help them to better understand teaching with educational technologies. We offer the idea of TPCK-based "activity types," rooted in previous research about content-specific activity structures, as an alternative to existing professional development approaches, explaining how this new way of thinking may more authentically and effectively assist teachers' and teacher educators' technology integration efforts.

Studies of K-12 teachers' instructional applications of educational technologies to date show many to be pedagogically unsophisticated; limited in breadth, variety, and depth; and not well integrated into curriculum-based teaching and learning (e.g., Cuban, 2001; Earle, 2002; McCrory-Wallace, 2004; Zhao, Pugh, Sheldon & Byers, 2002). In a 20-year retrospective on U.S. educational technology policy, Culp, Honey, and Mandinach (2003) describe a mismatch between educational technology leaders' visions for technology integration and how most practitioners use digital tools. Researchers emphasize technology uses that support inquiry, collaboration and reformed practice, while teachers tend to focus upon using presentation software, learner-friendly Web sites, and management tools to enhance existing practice. McCormick & Scrimshaw (2001) label these currently predominant uses for information and communication technologies as "efficiency aids" and "extension devices," differentiating them from "transformative devices" (p. 31), which "transform the nature of a subject at the most fundamental level" (p. 47). These authors suggest that such curricular transformation happens only in those few content areas (e.g., music, literacy, and art) that are "largely defined by the media they use" (p. 47).

The discrepancy between the hoped-for uses of educational technologies and the more prevalent efficiency and extension applications is rooted in the nature of efforts to date by K-12 schools and university partners to encourage technology use in classrooms. Five general approaches dominate past and current efforts for technology integration: software-focused initiatives; demonstrations of sample resources, lessons, and projects; technology-based educational reform efforts; structured and/or standardized professional development workshops or courses; and technology-focused teacher education courses.

1. *Software-focused initiatives.* One of the earliest examples of software-focused technology integration approaches was in the area of mathematical learning and general problem-solving skill development through students' use of the programming language Logo. Later software-based integration attempts make use of integrated learning system (ILS) software, which provides individualized instruction while tracking students' learning needs and progress.

2. *Demonstrations of sample resources, lessons and projects.* Teachers often demand classroom-based and student–tested examples of appropriate technology use. Given this demand, it is not surprising that there is a wide range of sources (such as magazines, books, Web sites, and conference presentations) that recommend curriculum-based lessons, projects, and online resources that have been used successfully by teachers. It is assumed that teachers who decide to use any of these will customize them to fit their particular, local contexts.

3. *Technology-based educational reform efforts.* These larger-scale, often grant-funded projects, such as Apple's Classrooms of Tomorrow (ACOT) 10-year initiative (Sandholtz, Ringstaff & Dwyer,

1997), are usually organized around new visions for learning and teaching that are realized through novel uses of educational technologies. Projects are implemented primarily through systemic planning and intensive professional development efforts supported by the acquisition of hardware and software.

4. *Structured/standardized professional development workshops or courses.* Large-scale professional development initiatives such as Marco Polo and PBS' TeacherLine are pre-structured options that are adopted locally or by school district, region, or state. Some, like Marco Polo, are structured as cascading professional development, where the parent organization trains district, regional, or state-level trainers, who, in turn, offer the prepackaged professional development to groups of teachers in their own jurisdictions. Others, like TeacherLine, license a wide variety of professional development courses to districts, regions, or states, so that teachers can pursue them in more individualized ways.

5. *Technology-focused teacher education courses.* Teacher education institutions – either colleges/universities or districts/regions working alone or collaboratively – offer educational technology courses to teachers, delivered online or face-to-face. These can serve as recertification courses taken on an unclassified student basis or as elements of graduate or undergraduate programs in education.

Though different from each other, these approaches tend to initiate and organize their efforts according to the educational technologies being used, rather than students' learning needs relative to curriculum-based content standards—even when their titles and descriptions address technology integration directly. They are "technocentric" (Papert, 1987) in that they begin with technologies' affordances and constraints, then attempt to discern how the technologies can be integrated successfully into content-based learning at different levels. We suggest that this approach is inadequate, as the comparatively weak and sporadic instances of technology integration in most K-12 content areas thus far demonstrate.

The technocentric approaches that have characterized most technology integration efforts to date have typically given short shrift to two key domains—content and pedagogy. The five approaches outlined above assume implicitly that irrespective of whether one is teaching middle school science, high school social studies, or elementary language arts, the kinds of technology knowledge required of teachers are the same. This ignores the variation inherent in different forms of disciplinary knowledge and inquiry as well as the kinds of pedagogical strategies that are most appropriate for teaching this content. Different disciplines have differing organizational frameworks, established practices, ways of acknowledging evidence and proof, and approaches for developing knowledge. Moreover, knowledge of these disciplinary factors is necessary but not sufficient without knowledge of the appropriate pedagogical strategies for each of these content areas (AACTE Committee on Technology & Innovation, in press).

Technology integration approaches that do not reflect disciplinary knowledge differences, and the corresponding processes for developing such knowledge, ultimately are of limited utility and significance, ignoring as they do the full complexity of the dynamic realities of teaching effectively with technology. Understanding that introducing new educational technologies into the learning process changes more than the tools used—and that this has deep implications for the nature of content-area learning, as well as the pedagogical approaches which teachers can select among--is an important and often-overlooked aspect of technology integration approaches to date.

Introducing Technological Pedagogical Content Knowledge

Recently, considerable interest has surfaced in using the notion of Technological Pedagogical Content Knowledge (TPCK) (Mishra & Koehler, 2006; Koehler & Mishra, in press) as a framework for the teacher knowledge required for effective technology integration, because TPCK reconnects technology to curriculum content and specific pedagogical approaches. The TPCK framework describes how teachers' understandings of technology, pedagogy, and content can interact with one another to produce effective discipline-based teaching with educational technologies. In this framework (see Figure 1), there are three interdependent components of teachers' knowledge: Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK).

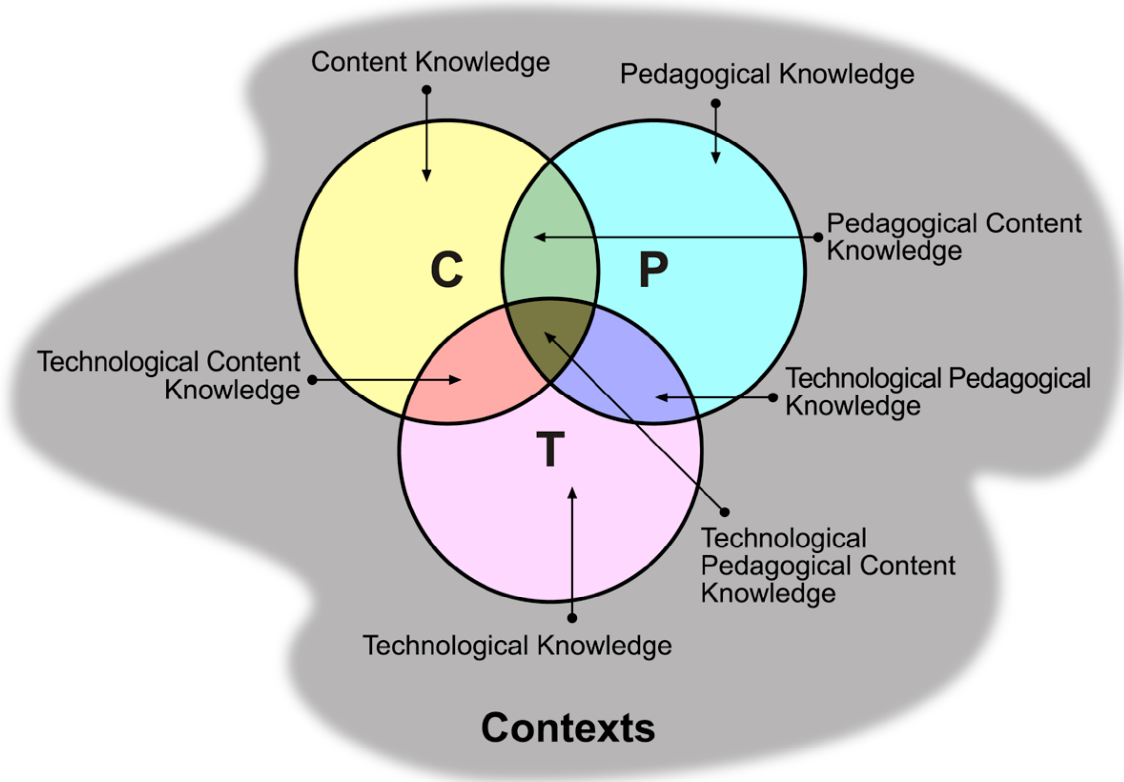

Figure 1. The TPCK framework and its knowledge components (Koehler & Mishra, in press)

Equally important to the model, and particularly relevant to the argument we put forth in this paper, are the interactions among these bodies of knowledge, represented as Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical Content Knowledge (TPCK). In the following sections we will explore each of these components, with particular emphasis upon the intersections among the three primary components.

Content Knowledge (CK)

Content Knowledge is knowledge about the actual subject matter that is to be learned or taught, including, for example, middle school science, high school history, undergraduate art history, or graduate level astrophysics. Knowledge and the nature of inquiry differ greatly among content-areas and it is critically important that teachers understand this about the subject matter that they teach. As Shulman (1986) noted, this includes knowledge of concepts, theories, ideas, organizational frameworks, knowledge of evidence and proof, as well as established practices and approaches toward developing such knowledge. In the case of art appreciation, such knowledge would include knowledge of art history, famous paintings, sculptures, artists and their historical contexts, as well as knowledge of aesthetic and psychological theories for evaluating art. The cost of not having a comprehensive base of content knowledge can be quite prohibitive; students can receive incorrect information and easily develop misconceptions about the content area (National Research Council, 2000; Pfundt, & Duit, 2000).

Pedagogical Knowledge (PK)

Pedagogical Knowledge is deep knowledge about the processes and practices or methods of teaching and learning, encompassing educational purposes, values, aims, and more. This is a generic form of knowledge that applies to student learning, classroom management, lesson plan development and implementation, and student evaluation. It includes knowledge about techniques or methods used in the classroom; the nature of the target audience; and strategies for evaluating student understanding. A teacher with deep pedagogical knowledge understands how students construct knowledge and acquire skills in differentiated ways, and how they develop habits of mind and dispositions toward learning. As such, pedagogical knowledge requires an understanding of cognitive, social and developmental theories of learning and how they apply to students in the classroom.

Technology Knowledge (TK)

Technology knowledge is always in a state of flux—more so than the other two "core" knowledge domains in the TPCK framework (content and pedagogical knowledge). This makes defining and acquiring it notoriously difficult. Technology is continually changing, and keeping up-to-date with technological developments can become a full-time job, in and of itself. This also means that any definition of technology knowledge is in danger of becoming outdated by the time this text has been edited, proofread and published. There are, however, certain ways of thinking about and working with technology that can apply to all technological tools. In that sense, our definition of TK is close to that of Fluency of Information Technology (FITness) as proposed by Committee on Information Technology Literacy of the National Research Council (NRC, 1999). They argue that FITness goes beyond traditional notions of computer literacy to require that persons understand information technology broadly enough to apply it productively at work and in their everyday lives. FITness therefore requires a deeper, more essential understanding and mastery of information technology for information processing, communication, and problem solving than does the traditional definition of computer literacy. This conceptualization of TK does not posit an "end state" but rather sees it developmentally--as evolving over a lifetime of generative, open-ended interactions with technology.

Pedagogical Content Knowledge (PCK)

Pedagogical content knowledge (PCK) is the intersection and interaction of pedagogy and content knowledge. PCK is consistent with, and similar to Shulman's (1986) conceptualization of teaching knowledge applicable to a specific content area. It covers knowledge of the core business of teaching, learning, curriculum, assessment and reporting, expressed, for example, in the conditions that promote learning and the links among curriculum, assessment and pedagogy. An awareness of students' prior knowledge, alternative teaching strategies, common content-related misconceptions, how to forge links and connections among different content-based ideas, and the flexibility that comes from exploring alternative ways of looking at the same idea or problem, and more, are all expressions of pedagogical content knowledge, and are essential to effective teaching.

Technological Pedagogical Knowledge (TPK)

Technological pedagogical knowledge is an understanding of how teaching and learning change 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. It requires building a deeper understanding of the constraints and affordances of particular technologies and the educational contexts within which they function best.

An important part of TPK is developing creative flexibility with available tools in order to repurpose them for specific pedagogical purposes. Consider, for example, the whiteboard as an educational tool. Although this technology has been in use for a long time, its very nature in some ways pre-supposes the kinds of functions it can serve. Because it is usually placed in the front of the classroom and is therefore usually under the control of the teacher, its location and use impose a particular physical order upon the classroom, determining the placement of tables, chairs, and therefore students, thus framing the nature of student-teacher interaction. Yet it would be incorrect to say that there is only one way in which whiteboards can be used. One has only to compare the use of a whiteboard in a brainstorming meeting in a business setting to see a rather different use of this technology than what a traditional classroom implementation might appear to be. In such a setting, the whiteboard is not under the purview of a single individual, but rather it can be used by anybody in the group, and it becomes the focal point around which discussion and the negotiation/construction of meaning occurs.

The flexible use of tools as a component of TPK becomes particularly important because most popular software programs 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 use in business environments. Web-based technologies such as blogs or podcasts are designed for purposes of entertainment, communication, and/or social networking. Teachers, therefore, need to develop skills that allow them to "reconfigure" technologies for their own pedagogical purposes. Thus, TPK requires a forward-looking, creative and open-minded seeking of technological application, not for its own sake, but for the sake of advancing student learning and understanding.

A large proportion of technology-based activities that have been developed in the past to illustrate technology integration, through their lack of design emphasis upon the demands of the content to be covered, fall within this form of knowledge. These include generic strategies, such as keypals, telefieldtrips, blogging/journaling, preparing PowerPoint presentations, building Web sites, and podcasting. Each of these activities is typically described in content-neutral terms, assuming that each would work just as well within any content area.

Technological Content Knowledge (TCK)

Technological Content Knowledge (TCK) includes an understanding of the manner in which technology and content influence and constrain one another. In planning for instruction, content and technology are often considered separately, and therefore can be regarded as "Somebody Else's Problem" (SEP). It is assumed that developing content is what content experts do (i.e., history is developed by historians and physics by physicists), while technologists develop technologies (e.g., hypertexts or overhead projectors) and technology integration strategies. Thus, when we think of subject matter that students study in school, we often do not think of the content's relationships to the digital and nondigital technologies that learners and teachers use. However, historically, technology and knowledge have a deeply connected relationship. Progress in medicine, history, archeology and physics have emerged, in part, from the development of new technologies that afford the representation and manipulation of data in new and fruitful ways. They often have led to fundamental changes in the nature of the disciplines themselves. Roentgen's discovery of X-Rays, for example, changed both diagnostic processes and the nature of knowledge in medicine. The Carbon-14 dating technique similarly revolutionized the field of archeology.

Consider also how the advent of the digital computer changed the nature of physics and mathematics work, placing a greater emphasis upon the role of simulation in understanding phenomena.

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—specifically, the kinds of content-based representations that can be constructed--can be changed by the application of different technologies, alone and in combination. Teachers must understand which technologies are best suited for addressing which types of subject-matter learning, and how content dictates or shapes the technological application—and vice versa. For this they need to understand the three key ways in which technology and content relate to one another.

First, the advent of new technology has often changed fundamentally what we consider to be disciplinary content. In addition to the examples mentioned above, consider how the discovery of radiation changed the way we understand the evolution of life, while the invention of hypertext transfer (HTTP) and other Internet protocols dramatically changed the ways in which we live, work and communicate. Content shapes new technologies and new uses for existing technologies, while at the same time, the affordances and constraints of technologies shape disciplinary content.

Second, technology is not neutral with regard to its effects upon cognition. Different technologies (or media) engender different mindsets or ways of thinking (Koehler, Yadav, Phillips, & Cavazos-Kottke, 2005; Mishra, Spiro, and Feltovich, 1996). Every new technology--from the process of writing to talking on the telephone; from the camera to the digital computer--has had its effects on human cognition. For example, the advent of moveable type and printing in the fifteenth century was followed by a series of dramatic changes in all aspects of social, cultural, political and scientific life in Europe and eventually, most of the rest of the world. Many of the effects of the invention and diffusion of print can be traced to certain specific properties of print media. Print created objects that were mobile, immutable, presentable, and readable; and these properties led to fundamental changes in human cognition (Latour, 1990). They seemed to ensure that discussions could be carried beyond the conversational arena that predominated in the oral cultures of the time. These print objects allowed ideas to be transported without change to their essential natures, so that they could be universally and consistently understood in ways that more mutable, oral retellings could not. A similar change--though this time toward flexibility and connectivity--can be seen through the development of Web-based texts that are nonlinear, unbounded, and dynamic. This is especially apparent in the so-called "Web 2.0" technologies that foster communal and shared knowledge generation.

Finally, technological changes offer us new metaphors and languages for thinking about human cognition and our place in the world. Viewing the heart as a pump, or the brain as an information-processing machine, are just some of the ways in which technologies have provided new perspectives for understanding phenomena. These representational and metaphorical connections are not superficial. Considering the brain as being akin to a clay tablet, for example, offers a very different view of cognition and learning than considering it to be akin to an information-processing machine. Having these metaphors and analogies as part of general cultural consciousness will influence how technologies will be appropriated for teaching and learning.

Technological Pedagogical Content Knowledge (TPCK) – "The Holy Grail"

Underlying truly meaningful and highly skilled teaching with technology, we argue, is Technological Pedagogical Content Knowledge (TPCK). TPCK is different from knowledge of all three concepts individually and in their individual intersections. It arises instead from multiple interactions among content, pedagogical, and technological knowledge. TPCK encompasses understanding the representations of concepts using technologies; pedagogical techniques that apply technologies in constructive ways to teach content in differentiated ways according to students' learning needs; knowledge of what makes concepts difficult or easy to learn and how technology can help redress conceptual challenges; knowledge of students' prior content-related understanding and epistemological assumptions; and knowledge of how technologies can be used to build on existing understanding to develop new epistemologies or strengthen old ones. TPCK is a form of knowledge that expert teachers bring into play any time they teach.

Many aspects of these ideas are not new. As Shulman (1986) and others after him have argued, teachers' knowledge for effective practice requires the transformation of content into pedagogical forms. What has been overlooked in most cases, we argue, are the critical roles that technologies play in this regard. For example, Shulman writes that developing PCK requires teachers to find

> …the most useful forms of representation of [the subject area's] 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. (p. 9)

What is interesting to note here is that each of the components described by Shulman—representations, analogies, examples, explanations and demonstrations--are constrained, constructed and in critical ways defined by digital and nondigital technologies. In one sense, there is no such thing as pure content, pure pedagogy, or pure technology. It is important for teachers to understand the complex manner in which all three of these domains co-exist, co-constrain and co-create each other.

Each instructional situation in which teachers find themselves is unique; it is an interweaving of these three factors, and accordingly, there is no single technological solution that will function equally well for every teacher, every course, or every pedagogical approach. Rather, solutions' successes lie in teachers' abilities to flexibly navigate the space delimited by content, pedagogy, and technology and the complex interactions among these elements as they are demonstrated in the multitude of specific instructional situations and contexts. Ignoring the complexity inherent in each knowledge component--or the complexities of the relationships among the components--can lead to oversimplified solutions or even failure. Thus, teachers need to develop fluency and cognitive flexibility not just in each of these key domains—content, technology, and pedagogy--but also in the manners in which these domains interrelate, so that they can effect maximally successful, differentiated, contextually sensitive learning.

Developing the Interactional Components of TPCK

How are teachers to acquire an operational understanding of the complex relationships among content, pedagogy, and technology? Typical approaches suggest implicitly that teachers need only be trained to use particular educational technologies and exposed to possible curriculum-based uses of those tools and resources. Approaches that teach only skills (technology or otherwise), however, are insufficient. Learning about technology is different than learning what to do with it instructionally. Teaching technology skills (the T in the model above) in isolation does little to help teachers develop knowledge about how to use technology to teach more effectively (TPK), its relationship to disciplinary content (TCK), or how to help students meet particular curriculum content standards using technologies appropriately (TPCK) in their learning.

The application of the TPCK framework to the development of teacher knowledge does not imply a rigid or algorithmic adherence to a single approach to technology integration. For example, one teacher interested in integrating technology in history may consider the use of primary sources available on the Internet, while another may choose to have students develop hypertexts that reveal multiple cause-effect relationships among related historical events. A mathematics teacher may choose to utilize the representational capabilities of mathematical software--graphs, charts, and symbols--or to help her students to explore dynamic methods of geometric proof digitally. Thus, the development and demonstration of teachers' TPCK knowledge requires flexibility and fluency--not just with curriculum-based content, but also with pedagogy and technology—remembering that *each influences the other in pervasive ways.*

In speaking of Shulman's notions of PCK, Beyer, Feinberg, Pagano, and Whitson (1989) suggested that PCK "implicitly denies the legitimacy, even as a matter of conceptual convenience, of the forced disjuncture between thought and action and content and method" (p. 9). We would argue that this denial of the split between thought and action, and content and method is true of TPCK as well. TPCK should not be described in isolation from techniques for developing it. Koehler & Mishra (2005) have explored learning-by-design approaches to the development of TPCK. Here, we suggest a different approach to TPCK-based professional development for teachers that foregrounds PCK as it shapes and is shaped by the particular affordances and constraints of different digital and nondigital educational technologies.

Using Content-Based Activity Types to Develop TPCK

To help teachers to develop TPCK in ways that attend to the particular demands of different subject matter domains, we suggest first creating awareness of the range of possible learning *activity types* (Harris & Hofer, in press) within a particular content area, then helping teachers to know how to select among and combine activity types in ways that are congruent with students' standards-based, differentiated learning needs and preferences. The approach is based upon an empirical assumption that maximally appropriate and effective instruction with technology is best planned after teachers are familiar with the complete range of learning activity types (supported by both digital and nondigital technologies) in a particular curriculum-related discipline. Since content, pedagogy, and technology knowledge are so interrelated and interdependent, and given the situated, event-structured, and episodic nature of teachers' knowledge (Putnam & Borko, 2000), it serves to reason that there are identifiable TPCK-related learning activity types within each curriculum-based discipline that can be used as situated and flexible cognitive planning tools (Harris, in press).

Origins of Content-Based Activity Types

Activity types are based upon research catalyzed by and concomitant with teacher educators' realization of the critical importance of Shulman's notions of pedagogical content knowledge. They are more "teacher-friendly" versions of the "activity structures" of social semiotic discourse analyses, and later, science and mathematics education literature. Activity structures are comprised of the "activity segments," first examined and explicated by ecological psychologists—that is, parts of lessons, each of which has a particular focus, format, setting, participants, materials, duration, pacing, cognitive level, goals, and level of student involvement (Stodolsky, 1988). Activity structures are combinations of activity segments recognizable to and used by teachers when planning instruction (e.g., "KWL activities"). Windschitl (2004), for example, when recommending pedagogical practice for science labs, identifies several lab-related activity structures, defining the term as follows.

> The term "activity structure" is borrowed from the sociocultural theorists, meaning a set of classroom activities and interactions that have characteristic roles for participants, rules, patterns of behavior, and recognizable material and discursive practices associated with them. "Taking attendance," "having a discussion," and "doing an experiment" could all be considered activity structures. While the term "activities" refers to specific phenomena occurring in classrooms, the structures underlying these are more general and applicable across multiple contexts. (p. 25)

Polman (1998) sees activity structures functioning on both classroom and school levels—and beyond. To him, predominant activity structures are cultural tools that perpetuate and standardize communication patterns—and therefore interaction norms and expectations—primarily according to teachers' memories of dominant discourse patterns from their own school-related childhood experiences. Some activity structures, therefore, can represent a mismatch between teachers' and students' differing socioculturally based expectations for teacher-student and student-student interaction (e.g., preferences for competitive or collaborative schoolwork), and therefore should be selected from as culturally competent a stance as possible. When a paradigmatically new teaching approach is attempted, Polman argues, since there isn't an "obvious set of well-established cultural tools to structure... interaction," (p. 4) teachers' resulting confusion and resistance can undermine educational reform efforts. For this reason, we advocate conscious identification, explication, and exploration of new (or revised) technologically-enhanced activity structures, which, with experience, we have learned to refer to as "activity types" to make their nature more transparent to teachers.

A classroom-based activity structure familiar to most educational researchers emerged from the study of classroom-based discourse. Mehan's (1979) I-R-E (teacher initiation, student reply, teacher evaluation) sequence was the first commonly cited discursive structure in educational literature. Lemke (1987) applied the notion of recurring discourse structure to the social semiotics of science education more broadly, noting that "every meaningful action in the classroom makes sense as part of some recurring semiotic pattern," (p. 219) and that every action has both interactional and thematic meaning.

That meaning unfolds, according to Lemke, within two independent discourse structures: activity structures and thematic structures. Activity structures are “recurring functional sequences of actions” (p. 219) and thematic structures are familiar ways of speaking about a topic, such as the curriculum-based focus of a unit or lesson (Windschitl, 2004). Lemke’s underlying assertion is that meaning cannot be separated from action; the structure of curriculum content, therefore, cannot be separated from the structure of content-related learning activities. Given the similar underlying assumptions of TPCK’s interdependence described earlier, it is probable that tool and resource use—both digital and nondigital—can similarly not be separated from content/theme and activity structure. Therefore, TPCK-related activity types for teachers’ use should be conceptualized and presented in terms of their specific disciplinary discourses, *and not according to the technologies incorporated.* Moreover, given the content-based nature of activity structures (Stodolsky, 1988) in general, using TPCK-based activity types explicitly in working with teachers represents a promising approach to professional development in technology integration.

Cultivating Teachers’ Use of Activity Types

Several educational researchers have begun to examine the intentional cultivation and use of activity structures in professional development for teachers. Kolodner & Gray (2002), for example, proposed a system of “ritualized” learning activity structures to assist learning and teaching in project-based science work. The authors recommended ritualizing activity structures at both strategic and tactical levels – that is, in sequencing both the steps for participating in a particular type of learning activity and the order of activities that comprise a project or unit. Kolodner & Gray’s activity structures are specific to the science-related skills that each helps students to develop. For example, there are three different types of presentations included: for ideas, for experimental results, and for experiences with multiple solutions to similar problems. The researchers discovered that--contrary to common expectations that naming too many different activity structures would overwhelm students and teachers--such fine-grained differentiation actually assisted both learners and instructors in knowing what to expect from, how to participate in, and how each activity type is connected to the development of content-specific processes and goals. The structures appeared to “articulate and normalize a sequence of activities and setting expectations about how and when to carry them out.” (“Ritualized” Activity Structures section, para. 3)

Polman’s (1998) 2-year classroom-based study sought to document a project-based alternative to the traditional I-R-E activity structure. He discovered and named a B-N-I-E structure being used in a middle school science class, in which students “bid” by suggesting topics that they would like to research, then “negotiated” the details of the projects based upon those possible topics, then “instantiated” their understanding with work on the project according to their understanding of the instructor’s guidelines, then received and considered formative “evaluation” from the teacher on their work. The evaluation results then formed the basis for a new recursion of the B-N-I-E sequence as the students revised and continued their learning.

Polman’s research continued as he then tested the B-N-I-E activity structure in a different discipline: history. He found that the structure could be modified to accommodate another curriculum area, but that the adaptation must involve choices “along the dimensions of act (what) and agency (how)” (p. 22) because the nature of inquiry and expression in different disciplines differ in essential ways—for example, between a lab report and an historical narrative. Polman’s work with the same activity structure in two disparate disciplines demonstrates the discipline-specific (not transdisciplinary) nature of activity structures and types.

How (if at all) are activity structures/types connected to larger school-based social, professional, and organizational structures and networks? During an in-depth study of science education practices in Japan, Linn, Lewis, Tsuchida, & Songer (2000) compared the presence and use of science activity structures in multiple classrooms. They found the activity structures—to the expressed surprise of the researchers—to be consistently present and similarly described by both students and teachers. The structures were framed by the Japanese participants in terms of what students do during each science-related learning experience. The researchers hypothesized that the highly collaborative nature of Japanese teacher interactions may have yielded the similarities in descriptions and discussions. Yet contrary to popular U.S. perceptions, “Japanese teachers ultimately choose the instructional approaches they will use in the classroom,” but “shared research lessons may offer opportunities for teachers to collectively build and refine not just instructional techniques, but also norms about what is good instruction.” (p. 11) This points to an essential feature of successful use of activity structures/types as instructional planning/design tools: as Linn et al. recommend, they are best used flexibly and in the context of active teacher discourse communities to “enable deep, coherent instruction.” (p. 4)

What happens when a new activity structure—for example, the WebQuest—is used primarily without the active professional discourse that Linn et al. suggest? Dodge’s (2001) recommendations to teachers of “five rules for writing a great WebQuest” were created in response to the widespread misapplication of the activity structure. As Dodge described,

> A quick search of the Web for the word *WebQuest* will turn up thousands of examples. As with any human enterprise, the quality ranges widely....Some of the lessons that label themselves WebQuests do not represent the model well at all and are merely worksheets with URLs. (p. 7)

Dodge and March originally intended the WebQuest to be an inquiry-based activity that requires students' use of information found online at analysis, synthesis, and evaluation levels (Dodge, 1995), applicable to any content area and most grade levels. With posted evaluation standards now available and encouraged for teachers' use (Dodge, Bellofatto, Bohl, Casey & Krill, 2001), WebQuests' creators are hopeful that a greater proportion of newly created WebQuests will reflect the purposes for and types of learning originally conceptualized. Yet we wonder whether this content-neutral activity type is, by virtue of its technological (Web-based) emphasis, highly prone to instructional application that is pedagogically mismatched with its original intent and design. The same could be suggested for other technology-based learning activity types mentioned earlier: keypals, telefieldtrips, blogging/journaling, educational podcasting, and more. If teaching and learning are conceptualized and characterized in action by teachers primarily according to content matter (Stodolsky, 1988), then the design of instruction and requisite professional development for teachers should be similarly organized, being offered predominantly by content area, and only concomitantly by technological and pedagogical attributes.

Sample Content-Based Activity Types

Using a content-based approach to professional development in technology integration rooted in several decades of research on activity segments and structures, teachers can learn to recognize, differentiate, discuss, select among, combine, and apply TPCK-based activity types in curriculum standards-based instructional planning. By planning with activity types, teachers can function as designers in time-efficient ways that accommodate the crowded and pressured nature of their daily schedules.

The first taxonomy of content-based, TPCK-related learning activity types has been developed for the social studies. Forty distinct activity types were identified from structural analyses of social studies learning activities used in classrooms, divided into 15 *knowledge-building* and 25 *knowledge expression* structures. Knowledge expression activity types are further divided into activities that emphasize either *convergent* or *divergent* thinking processes.

Knowledge-building activities are those in which students build content-related understanding through information-based processes. The names and brief descriptions of each of the 15 knowledge-building social studies activity types appear in Table 1, below.

Table 1

Knowledge-Building Activity Types (Harris & Hofer, in press)

Activity Type	Brief Description
Read Text	Students extract information from textbooks, historical documents, census data, etc.
View Presentation	Students gain information from teachers, guest speakers and their peers
View Images	Students examine both still and moving (video, animations) images
Listen to Audio	Students listen to recordings of speeches, music, radio broadcasts, oral histories, and lectures
Group Discussion	In small to large groups, students engage in dialogue with their peers
Field Trip	Students travel to physical or virtual sites connected with the curriculum
Simulation	Students engage in paper-based or digital experiences which mirror the complexity and open-ended nature of the real world
Debate	Students discuss opposing viewpoints with their peers
Research	Using a variety of sources, students gather, analyze, and synthesize information
Conduct an Interview	Face to face, on the telephone, or via email, students question someone on a chosen topic
Artifact-Based Inquiry	Students explore a topic using physical or virtual artifacts
Data-Based Inquiry	Using print-based and digital data available online; students pursue original lines of inquiry
Historical Chain	Students sequence print and digital documents in chronological order
Historical Weaving	Students piece together print and digital documents to develop a story
Historical Prism	Students explore print-based and digital documents to understand multiple perspectives on a topic

Knowledge expression activity types help students to deepen their understanding of content-related concepts using various types of communication. Convergent knowledge expression activities ask students to respond to or complete structured representations of prior knowledge-building. Table 2 summarizes the names and definitions of each of the 6 identified convergent knowledge expression activity types.

Table 2

Convergent Knowledge Expression Activity Types (Harris & Hofer, in press)

Activity Type	Brief Description
Answer Questions	Students respond to questions posed by the teacher, peers, or the textbook
Create a Timeline	Students develop a visual representation of sequential events
Create a Map	Students label existing maps or produce their own
Complete Charts/Tables	Students fill in teacher-created charts and tables or create their own
Complete a Review Activity	Students engage in some format of question and answer to review course content
Take a Test	Students demonstrate their knowledge through a traditional form of assessment

Divergent knowledge expression activity types in social studies help students to extend their content-related understanding via alternative forms of communication, as explained in Table 3, below.

Table 3

Divergent Knowledge Expression Activity Types (Harris & Hofer, in press)

Divergent Knowledge Expression Activity Type	Brief Description
Write an Essay	Students compose a structured written response to a teacher prompt
Write a Report	Students author a paper from a teacher or student derived topic
Develop a Presentation	In oral or multimedia format, students share their understanding with others
Develop a Knowledge Web	Using teacher or student created webs, students organize information in a visual/spatial manner
Generate an Historical Narrative	Using historical documents and secondary source information, students develop their own story of the past
Create a Diary	Students write from a first-hand perspective about en event from the past
Create a Newspaper/News Magazine	Students synthesize and present information in the form of a print-based or electronic periodical
Create an Illustrated Map	Students use pictures, symbols and graphics to highlight key features in creating an illustrated map
Engage in Civic Action	Students write to government representatives or engage in some other form of civic action
Engage in Historical Impersonation	Students portray historical figures
Produce an Artifact	Students create a 3-D or virtual artifact
Build a Model	Students develop a mental or physical representation of a course concept/process
Design an Exhibit	Students synthesize and describe key elements of a topic in a physical or virtual exhibit
Craft a Poem	Students create poetry connected with course content/ideas
Create a Mural	Students create a physical or virtual mural
Develop a Metaphor	Students devise a metaphorical representation of a content-based topic/idea
Draw a Cartoon	Students create a drawing or caricature of a content-based concept
Create a Film	Using some combination of still images, motion video, music and narration, students produce their own movie
Prepare a Performance	Students develop a live or recorded performance (oral, music, drama, etc.)

Note that each of these forty social studies activity types, as they have been described briefly here, do not typically privilege one particular type or class of educational technology. The same is true for the nascent research in developing and applying curriculum-based activity structures done by other researchers and mentioned earlier in this paper. Rather, in identifying and sharing activity types, the intention is to help teachers to become aware of the full range of possible curriculum-based learning activity options, and the different ways that digital and nondigital tools support each, so that they can efficiently select among, customize, and combine activity types that are well-matched to both students' differentiated learning needs and preferences and classroom contextual realities, such as computer access and class time available for learning activity work. Using this loosely structured design approach, as teachers plan classroom-based learning experiences, they keep students' needs, preferences, and relevant past experience in front-and-center focus, with curriculum standards and possible activity type selections in close visual peripheries, so that all are considered concurrently, albeit with differing emphases at different times and under different conditions.

Yet teachers' planning for students' learning should not be an activity-by-activity endeavor. Curriculum-based units, projects, and sequences are much more than the sums of their respective parts. Part of what a curriculum-based activity types approach to the development of TPCK addresses is how to combine individual activity types into engaging, appropriate, and authentic project or unit plans – but it is beyond the scope of this paper to describe these mechanisms here. (For more information, please see Harris & Hofer, in press.)

Future Work in TPCK-Based Technology Integration

For many experienced teachers, selecting, adapting, and designing learning activities, projects, and units is review work, but the awareness of how different digital and nondigital tools can be used in service of students' learning within each of the activity structures/types encompasses new information and/or new ways of thinking about planning for teaching. It is important that TPCK-based professional development for teachers be flexible enough to accommodate the full range of teaching philosophies, styles, and approaches. One way to ensure that flexibility is to share the full range of curriculum-based activity types within each discipline area, encouraging experienced educators to select among them based upon perceived appropriateness and advantage

– and to engage in this selection/combination process each time a new lesson, project or unit is planned.

Given that the first taxonomy of content-specific TPCK-based activity types has been created very recently, and that it refers to just one curriculum content area, it is clear that much more work in this line of inquiry must be done. Activity type taxonomies for each of the K-12 curriculum content areas, once developed, should be tested and refined according to what teachers discover and recommend when using them. The efficacy of students' learning that was planned using content-based activity types should be compared with that of instruction planned in more content-neutral, technologically focused ways. The efficacy of other TPCK-based professional development models, such as the learning-by-design approach mentioned earlier, should similarly be explored and compared, while creation of new models is encouraged.

Given the ever-evolving nature of educational research and practice, along with TPCK's defining elements: technology, pedagogy, and content, it is clear that what we face is at once a tall order and an appealing opportunity: to continue to invent, revise, expand, update, test, and otherwise explore the ways in which we understand and help teachers to develop technological pedagogical content knowledge. Due to the emergent and interdependent nature of TPCK, this can best be accomplished as a collaborative endeavor among content experts, educational technology developers, educational researchers, and pedagogical practitioners. We invite our readers to join us in this worthy endeavor.

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