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Teachers' Technological Pedagogical Content Knowledge and Learning Activity Types: Curriculum-based Technology Integration Reframed

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Abstract

In this paper we critically analyze extant approaches to technology integration in teaching, arguing that many current methods are technocentric, often omitting sufficient consideration of the dynamic and complex relationships among content, technology, pedagogy, and context. We recommend using the technology, pedagogy, and content knowledge (TPACK) framework as a way to think about effective technology integration, recognizing technology, pedagogy, content and context as interdependent aspects of teachers' knowledge necessary to teach content-based curricula effectively with educational technologies. We offer TPACK-based "activity types," rooted in previous research about content-specific activity structures, as an alternative to existing professional development approaches and explain how this new way of thinking may authentically and successfully assist teachers' and teacher educators' technology integration efforts. (Keywords: technological pedagogical content knowledge, learning activity types, technology integration, TPACK, TPCK)

INTRODUCTION

Studies of K–12 teachers' instructional applications of educational technologies to date show many to be pedagogically unsophisticated; they are limited in breadth, variety, and depth, and are not well integrated into curriculum-based teaching and learning (Groff & Mouza, 2008; Levin & Wadmany, 2008; Russell, O'Dwyer, Bebell & Tao, 2007; 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, whereas many teachers tend to focus on 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 technology-based curricular transformation happens only in those few content areas (e.g., music, literacy, and art) that are "largely defined by the media they use" (Harris, 2008, p. 47).

We argue that this discrepancy between a vision of transformative uses of educational technologies and the more prevalent efficiency and extension applications can be traced to the nature of how technology use in classrooms has been conceptualized and supported. Five general approaches dominate current and past technology integration efforts:

1. ***Software-focused initiatives.*** One of the earliest examples of software-focused technology integration approaches was in mathematical learning and general problem-solving skill development through students' use of the programming language Logo. Later software-based integration attempts made 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 proclivity, it is not surprising that there is a wide range of sources (such as magazine articles, books, Web sites, and conference presentations) that recommend curriculum-based lessons, projects, and online resources that teachers have used successfully. Underlying this effort is the assumption that successful use of instructional plans and educational resources is easily transferable among different classrooms.
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 Thinkfinity and PBS' TeacherLine are prestructured options that are adopted locally or by school district, region, or state. Some, like Thinkfinity, 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. These approaches are, in Papert's terms, "technocentric" (Papert, 1987) because they begin with technologies' affordances and constraints and the skills needed to operate them, then later attempt to discern how they can be integrated successfully into content-based learning at different levels. The comparatively weak and relatively sporadic instances of technology integration in most K–12 content areas suggest that such approaches are inadequate at best. Though educational technology leaders have been calling for content-based, pedagogically forward-thinking technology integration for more than a decade (e.g., Fisher, Dwyer, & Yokum, 1996; Means & Olson, 1997; Roblyer, Edwards, & Havriluk, 1997), professional development for teachers still emphasizes and is organized according to technologies' affordances and constraints (e.g., Friedhoff, 2008).

We argue that the greatest weakness of such technocentric approaches is that they have typically given short shrift to two key domains: content and pedagogy. The five approaches outlined above demonstrate implicit assumptions that the kinds of professional knowledge required of teachers for technology integration are the same, irrespective of whether one is teaching middle school science, high school social studies, or elementary language arts. This approach ignores the variation inherent in different forms of disciplinary knowledge and inquiry as well as the varied 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 (Koehler & Mishra, 2008). Moreover, knowledge of these disciplinary attributes is necessary but not sufficient without knowledge of the appropriate pedagogical strategies to use in each content area. Successful technology integration also recognizes the manner in which the myriad and ever changing contextual realities of the classroom and school influence what teachers do and what students learn (AACTE Committee on Innovation & Technology, 2008).

Technology integration approaches that do not reflect disciplinary knowledge differences, the corresponding processes for developing such knowledge, and the critical role of context ultimately are of limited utility and significance, as they ignore 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 among which teachers can select—is an important and often overlooked aspect of many technology integration approaches used to date.

In this paper we introduce one approach, TPACK-based learning activity types, which can help teachers successfully integrate technology into their practice. This approach goes beyond technocentric strategies and emphasizes the importance of helping teachers develop and apply integrated and interdependent

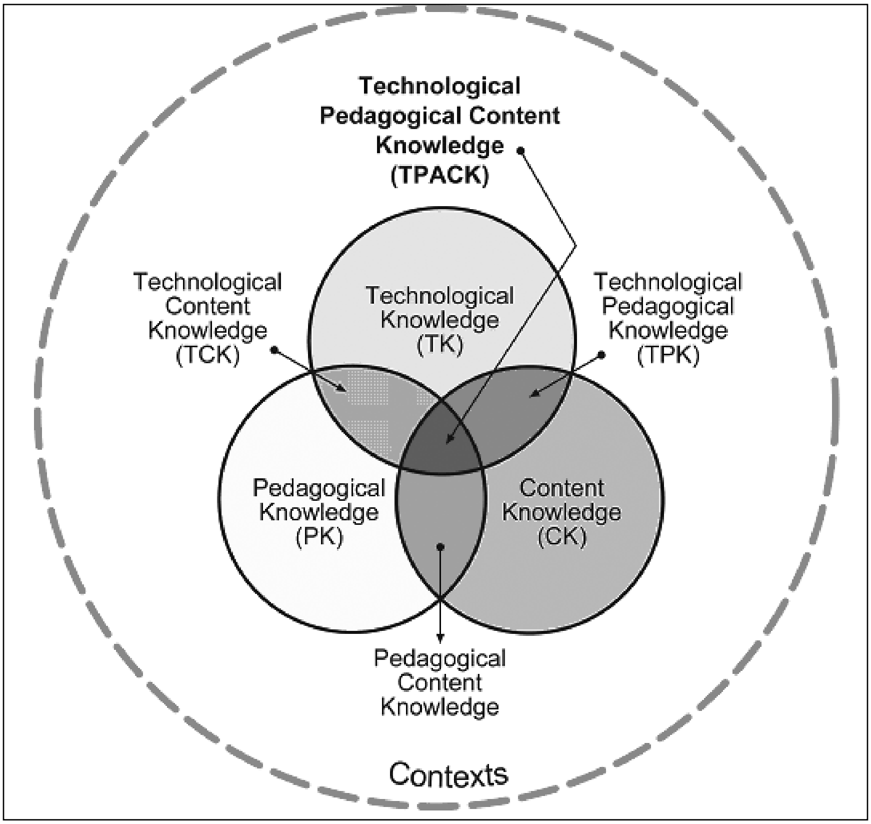

Figure 1: The TPACK Framework and Its Knowledge Components (Adapted from Koehler & Mishra, 2008)

understandings of technology, pedagogy, content, and context. Before describing this approach in detail, we offer a brief description of the parameters of teacher knowledge and its interrelated components using the TPACK[1] framework.

TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE (TPACK)

Considerable interest has surfaced recently in using the notion of technological pedagogical content knowledge (Mishra & Koehler, 2006; Koehler & Mishra, 2008) as a framework to understand teachers' knowledge required for effective technology integration. TPACK emphasizes the connections among technologies, curriculum content, and specific pedagogical approaches, demonstrating how teachers' understandings of technology, pedagogy, and content can interact with one another to produce effective discipline-based teaching

1 We use "technological pedagogical content knowledge," or TPCK, and "technology, pedagogy, and content knowledge," or TPACK, as synonyms.

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)—all framed within and influenced by contextual knowledge.

Equally important to this framework, and particularly relevant to the argument we put forth in this article, 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 (TPACK). In the following sections we will explore each of these types of knowledge, with particular emphasis on the intersections among technology, pedagogy, and content knowledge.

Content Knowledge (CK)

Content knowledge is knowledge about the 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 the disciplinary "habits of mind" appropriate to the subject matter that they teach. As Shulman (1986) noted, content includes knowledge of concepts, theories, ideas, organizational frameworks, methods of evidence and proof, as well as established practices and approaches toward developing such knowledge in a particular discipline. In the case of art appreciation, for example, such knowledge would include knowledge of art history, famous paintings, sculptures, the influence of artists' historical and social contexts, as well as knowledge of aesthetic and psychological theories for understanding and evaluating art. The cost of teachers having an inadequate content-related knowledge base can be quite prohibitive; students can develop and retain epistemologically incorrect conceptions about and within the content area (Bransford, Brown, & Cocking, 1999; Pfundt, & Duit, 2000).

Pedagogical Knowledge (PK)

Pedagogical knowledge is deep knowledge about the processes and practices of teaching and learning, encompassing educational purposes, goals, values, strategies, and more. This is a generic form of knowledge that applies to student learning, classroom management, instructional planning and implementation, and student assessment. It includes knowledge about techniques or methods used in the classroom, the nature of the learners' needs and preferences, and strategies for assessing student understanding. A teacher with deep pedagogical knowledge understands how students construct knowledge and acquire skills in differentiated ways, as well as 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.

Technological Knowledge (TK)

Technological knowledge is always in a state of flux—more so than content and pedagogical knowledge. This makes defining and acquiring it notoriously difficult. Keeping up to date with technological developments can easily become overwhelming to time-starved teachers. This also means that any definition of technology knowledge is in danger of becoming outdated by the time this text has been published. There are, however, ways of thinking about and working with technology that can apply to all technological tools, regardless of when they emerged. In that sense, our definition of TK is similar to the notion of Fluency of Information Technology ("FITness") as proposed by the Committee on Information Technology Literacy of the National Research Council (NRC, 1999). The committee argues that FITness goes beyond traditional notions of computer literacy to require that people 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 technology for information processing, communication, and problem solving than does the traditional definition of computer literacy. Also, this conceptualization of TK does not posit an "end state," but rather assumes TK to be developmental, evolving over a lifetime of generative interactions with multiple technologies.

Pedagogical Content Knowledge (PCK)

Pedagogical content knowledge 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 essential knowledge of teaching and learning content-based curricula, as well as assessment and reporting of that learning. An awareness of students' prior knowledge, alternative teaching strategies in a particular discipline, 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 and resources as they relate to disciplinarily and developmentally appropriate pedagogical designs and strategies. Developing TPK requires building an understanding of the potential benefits and limitations of particular technologies as they can be applied within particular types of learning activities, as well as the educational contexts within which these technologically supported activities function best.

An important aspect of TPK is the creative flexibility with available tools necessary in planning to use 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 presupposes 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 that whiteboards can be used. One has only to compare the use of a whiteboard in a brainstorming session in a design studio to see a rather different technological application. In this context, the whiteboard is not controlled by a single individual. Rather, it can be used by anybody on the collaborating team, and in this situation, it becomes the point around which discussion and the negotiation and construction of meaning occurs.

The flexible use of tools becomes particularly important because most popular software programs are not designed for educational purposes. Software such as the Microsoft Office Suite (Word, PowerPoint, Excel, Entourage, and MSN Messenger) is designed for use in business environments. Web-based technologies such as blogs and podcasts are designed for purposes of entertainment, communication, and social networking. Teachers, therefore, must have the knowledge and skills that allow them to appropriate technologies for pedagogical purposes, so that they can use Excel, for example, to help children organize and analyze data, and they can create podcasts as ways to share constructed knowledge with others. Thus, TPK must include 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 learning activities that have been developed in the past to illustrate technology integration, through their lack of emphasis upon content and pedagogy, illustrate an incomplete and comparatively superficial form of TPK. Examples include recommendations for use of generic strategies—such as keypals, telefieldtrips (Rogers, Andres, Jack, & Clausen, 1990), blogging/journaling, preparing PowerPoint presentations, building Web sites, and podcasting—without incorporating acknowledged PCK and PK. Such generic (and technocentric) strategies are described typically in content- and context-neutral terms, assuming that each would work just as well within any content area, at any grade level, and in any classroom.

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. It is assumed that developing content is what content experts do (i.e., historians develop history and physicists develop physics), whereas technologists develop technologies (e.g., hypertexts or overhead projectors) and technology integration strategies. When we think of subject matter that students study in school, we often do not think of curriculum content's relationships to the digital and nondigital technologies that learners and teachers use. Historically, however, technology and knowledge have been deeply connected. New understandings in medicine, history, archeology, and physics have emerged, in part, from the development of new technologies that afford the representation and manipulation of information and ideas in novel and fruitful ways. Using new technologies (or existing technologies in new ways) can prompt 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.

Effective teaching requires developing an understanding of the manner in which subject matter—specifically, the types of content-based representations that can be constructed within and across disciplines—can be changed by the use of different technologies. Teachers must understand which technologies are best suited for addressing which types of subject-matter, and how content dictates or shapes specific educational technological uses, and vice versa. We identify three ways in which technology and content have related 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 above, consider how the discovery of radiation changed the way we understand the evolution of life, whereas the invention of hypertext transfer (HTTP) and other Internet protocols dramatically changed the ways in which we work and communicate. Content (be it physics or engineering or sociology) shapes new technologies and offers new uses for existing technologies, while at the same time the affordances and constraints of technologies shape how this content is represented, manipulated, and applied.

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, & Feltovich, 1996). Every new technology—from the telephone to the camera to the digital computer—has had its effects on human cognition. For example, the advent of moveable type and printing in the 15th 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 texts that were mobile, immutable, presentable, and readable, and these properties led to fundamental changes in human cognition (Latour, 1990). They helped 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 and shared without change, so that they could be encountered in consistent ways that mutable, oral retellings would typically disallow. A similar change—though this time toward increased flexibility and connectivity—can be seen in the emergence 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 document generation.

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

Technological Pedagogical Content Knowledge (TPACK)

Underlying truly effective and highly skilled teaching with technology, we argue, is technological pedagogical content knowledge. TPACK is different from knowledge of its individual component concepts and their intersections. It arises instead from multiple interactions among content, pedagogical, technological, and contextual knowledge. TPACK encompasses understanding and communicating representations of concepts using technologies; pedagogical techniques that apply technologies appropriately 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, along with related technological expertise or lack thereof; and knowledge of how technologies can be used to build on existing understanding to help students develop new epistemologies or strengthen old ones. TPACK is a form of professional knowledge that technologically and pedagogically adept, curriculum-oriented teachers use when they teach.

Many aspects of these ideas are not new. As Shulman (1986) and others have argued, teachers' knowledge for effective practice requires the transformation of content into pedagogical forms. What has been overlooked in most cases, we suggest, are the critical roles that technology can play. 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)

It is interesting to note here that each of the components described by Shulman—representations, analogies, examples, explanations, and demonstrations—are constrained, constructed, and defined in critical ways by the affordances and constraints of the digital and nondigital technologies used to formulate and represent curriculum-based content. 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—and the contexts in which they are continually formed—co-exist, co-constrain and co-create each other.

Each instructional situation in which teachers find themselves is unique; it is the result of an interweaving of these interdependent factors. Accordingly, there is no single technological solution that will function equally well for every teacher, every course, or every pedagogical approach. Rather, a solution's success lies in a teacher's ability to flexibly navigate the spaces delimited by content, pedagogy, and technology, and the complex interactions among these elements as they play out in 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. 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 Interacting Components of TPACK

How are teachers to acquire an operational understanding of the complex relationships among content, pedagogy, technology, and context? As noted earlier, typical approaches to technology-related professional development are based upon assumptions that it may be enough to just expose teachers to particular educational technologies and possible curriculum-based uses of those tools and resources. Approaches that teach only skills (technology or otherwise) 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 while using technologies appropriately (TPACK) in their learning.

Using the TPACK framework to frame the development of teachers' knowledge does not necessitate a rigid or algorithmic adherence to a single approach to technology integration. For example, one teacher interested in integrating technology in history may consider 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. One mathematics teacher may choose to provide data sets that students represent with graphs and charts created with spreadsheet software, while another may choose to help her students to discover data patterns represented by the changing slope of a sine wave as it is constructed and altered dynamically with a graphing calculator. Thus, the development and demonstration of teachers' TPACK knowledge requires flexibility and fluency—not just with curriculum-based content, but also with pedagogy, technology, and context—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 TPACK as well. TPACK is most helpful when not described in isolation from techniques for developing it. It is not however, a professional development model. TPACK is a framework for teacher knowledge, and as such, it may be helpful to those planning professional development for teachers by illuminating what teachers need to know about technology, pedagogy, and content and their interrelationships. The TPACK framework does not specify how this should be accomplished, recognizing that there are many possible approaches to knowledge development of this type. Koehler & Mishra (2005) have explored learning-by-design approaches to the development of TPACK. Here, we suggest a different approach to TPACK-based professional development for teachers that foregrounds pedagogical content knowledge as it shapes and is shaped by the particular affordances and constraints of using different digital and nondigital educational technologies to assist students' curriculum-based learning.

USING LEARNING ACTIVITY TYPES TO DEVELOP AND APPLY TPACK

To help teachers to develop and use TPACK in ways that attend to the particular demands of different subject matter domains, we suggest that an important first step is creating awareness of the range of possible learning activity types (Harris & Hofer, 2006; Harris, 2008) within a particular content area, matching them to multiple ways that both digital and nondigital technologies can be used to support each type of learning activity. After determining the content and process goals for a particular lesson, project, or unit, teachers can then select from among the full range of activity types in that particular content area, combining the types selected in ways that are congruent with students' standards-based, differentiated learning needs and preferences. This approach is based on an empirical assumption that maximally appropriate and effective instruction with technology is best planned considering students' content-related learning needs and preferences primarily, selecting and applying technologies only in service of that curriculum-based learning.

The acknowledged focus in this approach to planning instruction is on content-based (and content-specific) pedagogy, which is facilitated by judiciously selected and implemented technologies. This emphasis is in accordance with the situated, event-structured, and episodic nature of teachers' knowledge (Putnam & Borko, 2000). Moreover, given that most teachers distinguish learning activities primarily by curriculum content (Stodolsky, 1988), and curriculum content is rooted in academic disciplines (Shulman, 1986) that are epistemologically (if not ontologically) distinct, a pedagogically focused approach to assisting the development of teachers' TPACK-in-action in the classroom should emphasize the differences among learning activities in different content areas rather than their similarities. In this way, it becomes easier for teachers to match particular activities to specific content-based learning goals and standards, and, more important, to interpret and implement these activities in ways that are congruent with the disciplinary roots of the discipline-based content that students are learning.

Origins of Content-based Activity Types

Activity types are based on research catalyzed by teacher educators' realizations of the critical importance of Shulman's (1986) notions of pedagogical content knowledge. They are a "friendlier" interpretation of the "activity structures" revealed in social semiotic discourse analyses of classroom interactions and later studied in science and mathematics classrooms (e.g., Lemke, 1987; Windshitl, 2004). Activity structures are comprised of "activity segments," which were first examined and explicated by ecological psychologists. Activity segments are the individual parts of a lesson, each of which has a particular focus, format, setting, participants, materials, duration, pacing, cognitive level, goals, and level of student involvement. Activity structures are combinations of activity segments that are recognizable to and used by teachers when planning instruction (e.g., "KWL activities") (Stodolsky, 1988). For example, the first commonly cited activity structure in educational literature—Mehan's (1979) I-R-E (teacher initiation, student reply, teacher evaluation) sequence—emerged from the study of classroom-based discourse.

In another example, Windschitl (2004) identifies several activity structures when recommending pedagogical practice for science labs, 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 in as student-centered a way as possible. When a paradigmatically new teaching approach is attempted, Polman argues, as 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. We believe a similar phenomenon can occur when a new technology is introduced. The resulting confusion and resistance can similarly undermine the process and goals of the learning activity. 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 and instructional uses more transparent to teachers.

Lemke (1987) applied the notion of recurring discourse structures to the social semiotics of science education more broadly, noting that every action in the classroom 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 the interdependence of TPACK's conceptual components described earlier, we argue that tool and resource use—both digital and nondigital—can similarly not be separated from content/theme and activity structure. Therefore, TPACK-related activity types for teachers' use should be conceptualized and presented in terms of their specific disciplinary discourses, and in conjunction with their technological affordances. Given the content-based nature of activity structures (Stodolsky, 1988) and teachers' experience teaching in specific content areas, using TPACK-based activity types represents a promising—and decidedly nontechnocentric—approach to professional development in technology integration.

Cultivating Use of Activity Types

Several educational researchers have examined 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. Their 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: presentations of ideas, of experimental results, and of experiences with multiple solutions to similar problems. Kolodner & Gray discovered that—contrary to 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 and how to participate in each activity type, plus how the activity is connected to the development of content-specific processes and goals.

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 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 (1998) 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 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 are activity structures/types connected to larger school-based social, professional, and organizational structures and networks, if they are indeed linked? During an in-depth study of science education practices in Japan, Linn, Lewis, Tsuchida, and Songer (2000) compared the presence and use of science activity structures in multiple classrooms. To their surprise, they found the activity structures to be consistently present and similarly described by both students and teachers. The Japanese participants framed the structures 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)

Matching Activity Types, Content, and Technologies

Technologies' affordances create opportunities for both enhancing existing learning activity types and creating new ones. Effective teaching requires knowledge of both the activity structures/types that are appropriate for teaching specific content and the manners in which particular technologies can be utilized as part of the lesson, project, or unit design. What happens when a new learning activity type is used without conscious attention to all aspects of the TPACK framework? In the following section, we examine WebQuests as one example of a comparatively new activity structure made possible (and by some accounts, "gone viral") by the advent of the Web.

WebQuests are inquiry-oriented activities in which some or all of the information with which learners engage comes from sources on the Internet. They represent an extremely popular activity structure and have been used in classrooms across the world. However, facilitating learning effectively with WebQuests is not a trivial task. In response to a widespread misapplication of this activity structure, Dodge (2001) published and promoted "five rules for writing a great WebQuest." As he 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, prone to instructional application that is mismatched both pedagogically and in terms of disciplinary content with its original intent and design. The same could be suggested for the other technology-based learning activity types mentioned earlier: keypals, telefield-trips, 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 professional development for teachers—including the ways that learning activity types are delineated and used—should be similarly organized within content areas while still considering the concomitant relationships among content, technology, pedagogy, and context.

Sample Activity Types

Using content foci as cognitive organizers for professional learning, teachers can learn to recognize, differentiate, discuss, select among, combine, and apply TPACK-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.

As an example, consider a taxonomy of TPACK-related learning activity types developed for the social studies. Harris and Hofer (2006; in press) identified 42 distinct learning activity types from structural analyses of social studies learning activities used in classrooms and reported in curriculum, research, pedagogical journals, and/or social studies methods texts. The activity types are divided into 13 knowledge-building and 29 knowledge-expression structures. Knowledge-expression activity types were further divided into activities that emphasize either *convergent* (6 types) or *divergent* (23 types) thinking processes.

In this article we connect these content-driven pedagogical strategies with specific and compatible technologies. The key idea is that not every technology

Table 1: Knowledge-Building Activity Types

Activity	Activity Description	Compatible Technologies
Read Text	Students extract information from textbooks, historical documents, census data, etc.	Books, Web browsers, CD-ROM, document viewers
View Presentation	Students gain information from teachers, guest speakers and their peers	Presentation software, note taking tools, audio/video recorders, whiteboards, concept mapping software
View Images	Students examine both still and moving (video, animated) images	Image/animation/video editing and display software
Listen to Audio	Students listen to recordings of speeches, music, radio broadcasts, oral histories, and lectures	Web sites, MP3 players, podcasts, radio, tape players, CD players
Group Discussion	In small to large groups, students engage in dialogue with their peers	Discussion forums, blogs, wikis, chatrooms
Field Trip	Students travel to physical or virtual sites connected with the curriculum	Video, virtual reality systems, online museums, galleries, and exhibitions
Simulation	Students engage in paper-based or digital experiences which mirror the complexity and open-ended nature of the real world	Virtual reality Web sites, simulation software, animations
Debate	Students discuss opposing viewpoints with their peers	Discussion forums, e-mail, chat
Research	Using a variety of sources, students gather, analyze, and synthesize information	Traditional and online books, encyclopedias, and journals; Wikipedia
Conduct an Interview	Face to face, on the telephone, or via e-mail, students question someone on a chosen topic	Telephone, VOIP (e.g., Skype), e-mail, chatrooms
Artifact-Based Inquiry	Students explore a topic using physical or virtual artifacts	Artifact kits, online museums and exhibitions, video games
Data-Based Inquiry	Using print-based and digital data available online, students pursue original lines of inquiry	Web sites, online databases, WebQuests
Historical Chain	Students sequence print and digital documents in chronological order	Web sites, primary sources (paper-based and virtual), timeline software
Historical Weaving	Students piece together print and digital documents to develop a story	Story construction software, concept mapping software, word processors, storyboard tools
Historical Prism	Students explore print-based and digital documents to understand multiple perspectives on a topic	Web sites, primary sources (paper-based and virtual), online newspapers, journals

Note: Based on Harris & Hofer, 2006; in press.

Table 2: Convergent Knowledge Expression Activity Types

Activity	Activity Description	Compatible Technologies
Answer Questions	Students respond to questions posed by the teacher, peers, or the textbook	Discussion boards, wikis, white-boards, quiz and polling software, textbooks
Create a Timeline	Students develop a visual representation of sequential events	Data mapping software, timeline software, concept mapping software
Create a Map	Students label existing maps or produce their own	Cartographic software, Google-Maps, drawing software
Complete Charts/ Tables	Students fill in teacher-created charts and tables or create their own	Excel or other data processing software, concept mapping software
Complete a Review Activity	Students engage in some format of question and answer to review course content	Courseware, quiz and polling software, wikis
Take a Test	Students demonstrate their knowledge through a traditional form of assessment	Quiz software, survey software

Note: Based on Harris & Hofer, 2006; in press.

is appropriate for use with each activity type. Rather, particular applications of specific technologies, based on their affordances, should be selected carefully to match the activity type(s) under consideration. There are three genres of learning activity types in the social studies that can be supported by varied uses of technology.

Typically completed first in a social studies project, unit, or series of connected lessons, knowledge-building activity types are those in which students build content-related understanding through information-based processes. The names and brief descriptions of each of the 13 knowledge-building social studies activity types, along with a list of compatible technologies, appear in Table 1.

Most often scheduled to follow knowledge-building activities, Harris and Hofer describe knowledge expression activity types for the social studies as those that help students deepen their understanding of content-related concepts using various types of communication. Convergent knowledge expression activities ask students to create, respond to, or complete structured representations of prior knowledge building. Table 2 summarizes the names and definitions of each of the six identified convergent knowledge expression activity types, and the technologies that are used most appropriately for each.

Finally, divergent knowledge expression activity types in social studies are described as those that help students to extend their content-related understanding via alternative forms of communication. Table 3 (pages 410–411) describes these 29 written, visual, conceptual, product-oriented, and participatory knowledge expression activity types, along with specific technologies that are compatible with each.

Table 3: Divergent Knowledge Expression Activity Types

Activity	Activity Description	Compatible Technologies
Written Knowledge Expression		
Write an Essay	Students compose a structured written response to a prompt	Word processing, wikis, blogs, concept mapping software
Write a Report	Students author a paper from a teacher or student derived topic	Word processing, wikis, blogs, concept mapping software
Generate an Historical Narrative	Using historical documents and secondary source information, students develop their own story of the past	Primary sources, timeline software, concept mapping software, word processors
Craft a Poem	Students create poetry connected with course content/ideas	Word processing software, wikis, blogs
Create a Diary	Students write from a first-hand perspective about an event from the past	Word processing, concept mapping, primary and secondary sources (paper based and virtual)
Visual Knowledge Expression		
Create an Illustrated Map	Students use pictures, symbols and graphics to highlight key features in creating an illustrated map	Cartographic software, graphics editing software, clip art, stock art, GoogleMaps
Create a Picture/Mural	Students create a physical or virtual mural	Multimedia editing and graphics tools
Draw a Cartoon	Students create a drawing or caricature of a content-based concept	Drawing/painting software, handheld drawing tools
Conceptual Knowledge Expression		
Develop a Knowledge Web	Using teacher- or student-created webs, students organize information in a visual/spatial manner	Concept mapping software, wikis, brainstorming aids, interactive whiteboards
Generate Questions	Students develop questions related to content/concepts	Word processing, wikis, Google Docs
Develop a Metaphor	Students devise a metaphorical representation of a content-based topic/idea	Image banks, graphics editors, multimedia authoring tools
Product-Oriented Knowledge Expression		
Produce an Artifact	Students create a 3D or virtual artifact	CAD/CAM software, virtual reality creation software
Build a Model	Students develop a mental or physical representation of a course concept/process	Modeling, simulation construction, graphics software, multimedia production tools
Design an Exhibit	Students synthesize and describe key elements of a topic in a physical or virtual exhibit	Presentation software, word processing, Web authoring tools, graphics tools
Create a Newspaper/News Magazine	Students synthesize and present information in the form of a print-based or electronic periodical	Desktop publishing software, word processing, wikis

Table 3 (Continued)

Activity	Activity Description	Compatible Technologies
Product-Oriented Knowledge Expression (Continued)		
Create a Game	Students develop a game, in paper or digital form, to help themselves and other students learn content	Word processors, imaging tools, Web authoring software, specialized game-making software
Create a Film	Using some combination of still images, motion video, music and narration, students produce their own movie	Multimedia recording and editing tools and software
Participatory Knowledge Expression		
Do a Presentation	In oral or multimedia format, students share their understanding with others	Presentation software, multimedia authoring tools, video and audio editing suites
Engage in Historical Role Play	Students portray historical figures	Presentation software, multimedia capture/editing software
Do a Performance	Students develop a live or recorded performance (oral, music, drama, etc.)	Word processing, storyboarding software, video/audio editing tools
Engage in Civic Action	Students write to government representatives or engage in some other form of civic action	Word processing, Web site design, blogs, wikis, e-mail

Note: Based on Harris & Hofer, 2006; in press

Note that each of these 42 social studies activity types, as they have been described briefly here, do not privilege one particular type or class of educational technology, nor do they recommend a particular pedagogical approach, in keeping with the situated and flexible aspects of the TPACK framework described earlier in this article. Instead, we acknowledge that different combinations of pedagogical strategies and technologies, each with unique affordances and constraints, are appropriate for different discipline-based curricula, differentiated student learning needs and preferences, and different contextual realities.

Our goal in identifying and sharing activity types, and the manner in which specific technologies are used more (or less) appropriately with each, is to help teachers become aware of the full range of possible curriculum-based learning activity options and the different ways that digital and nondigital tools support each. This can help teachers (and teacher educators) 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, teachers keep students' needs, preferences, and relevant past experience in front-and-center focus as they plan classroom-based learning experiences, with curriculum standards and possible activity-type (and technology) selections in close visual peripheries, so that all are considered concurrently, albeit with differing emphases at different times and under different conditions (Harris, 2008).

It is important to note that using these lists of activity types and technological aids should not be seen as the total process of instructional planning. Effective planning for students' learning is not merely an activity-by-activity endeavor, because curriculum-based units, projects, and sequences are much more than the sums of their respective parts, and their effective use requires related but distinct types of pedagogical, content, and technological expertise. Describing how use of activity types is integrated into instructional planning overall, and what the accompanying mechanisms of that holistic planning process are, is unfortunately beyond the scope of this article. Interested readers can track forthcoming publications that address the use of TPACK-based activity types in instructional planning by visiting the Learning Activity Types Wiki periodically at http://activitytypes.wmwikis.net.

CONCLUSION

Because teachers' TPACK is not limited to a particular approach to teaching, learning, or even technology integration, it is important that TPACK-based professional development for teachers be flexible and inclusive 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 teachers to select among them based on perceived appropriateness and advantage with reference to students' learning needs and preferences, and to engage in this selection/combination process each time they plan a new lesson, project, or unit.

Given that the first taxonomy of content-specific TPACK-based activity types has been tested comparatively recently, and that it refers to just one curriculum content area, it is clear that much more work in this line of inquiry needs to be done. Activity type taxonomies for other K–12 curriculum content areas—which will have been developed and posted by the time this article is in print for elementary literacy, mathematics, science, secondary English, and world language learning, in addition to the social studies activity types described here[2]—should be tested and refined according to what teachers and teacher educators discover and recommend when using them. Also, teachersand researchers should compare the efficacy of students' learning that was planned using content-based activity types with instruction planned in more content-neutral, technologically focused ways. They should similarly explore and compare the efficacy of other TPACK-based professional development models, such as the learning-by-design approach mentioned earlier, and the creation of additional models is encouraged.

The continual evolution of technology, pedagogy, and content often brings new learning activity types to light. This means that activity-type taxonomies

2 Activity-type taxonomies for these content areas, along with surveys to capture vetting feedback, are available at http://activitytypes.wmwikis.net/.

are not static entities, but rather continually evolving as we develop new technologies, new ways of representing content, and new ways of helping different students learn it. Given the ever evolving nature of educational research and practice, and of TPACK's defining elements, 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 TPACK. Due to the emergent and interdependent nature of this particular type of professional, applied knowledge, this can be best 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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