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Integrating Technology in Education: Moving the TPCK Framework towards Practical Applications

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This theoretical paper offers a conceptual interpretation of the Technological, Pedagogical, and Content Knowledge (TPCK) framework to include the role of context within practical classroom applications. Our interpretation suggests that the importance of these three knowledge bases fluctuate within each stage of teachers' planning and instruction, depending on classroom contexts and desired learning outcomes. Applications for the science classroom are provided. The implications of this conceptual interpretation offer pragmatic ways of understanding the TPCK model within preservice and inservice teacher education programs, professional development, and classroom practice.

Introduction

The deliberate inclusion of educational technologies into the classroom to enhance 21st century teaching and learning experiences continues to be an integral aspect of teacher education (Luu & Freeman, 2011; Windschitl, 2009). Despite the emergence of this as a critical attribute of modern teachers, there exists a limited understanding of the applications and conceptual grounding of theoretical frameworks in the educational technology literature that aim to inform the pragmatics of teaching and learning with technology (Angeli, 2005; Graham, 2011; Koehler & Mishra, 2008, Neiss, 2005). Through this realization, the development of conceptual understandings of various theoretical models are emerging towards informing teachers about appropriate technology integration, and increasing teacher cognition on purposeful technology use in the classroom (Angeli & Valanides, 2005; Bos, 2011; Graham, Burgoyne, Cantrell, Smith, St. Clair & Harris, 2009; Margerum-Lays & Marx, 2003; Mishra & Koehler, 2006).

In recognition of this, the purpose of this theoretical paper is to provide a conceptual interpretation of the Technological, Pedagogical, and Content Knowledge (TPCK) model towards a practical articulation of the construct. This interpretation is used to support a two-part thesis: (1) that there exists an oscillation of each knowledge base that fluctuates rather than remains static, and (2) that the proportion of each knowledge base is contextually relative. In order to achieve this, the following paper outlines: (a) a discussion of the factors, influences, and course structures for the integration of technology in education; (b) the TPCK framework and its role in preservice and inservice teacher instruction; (c) a discussion of our understandings of the 'spaces between' the TPCK model and relevant connections for science instruction; and, (d) practical examples of relative proportions and oscillation manifestations within classroom science instruction.

Technology Integration in Education: A Review of Factors and Influences

Teachers integrate technology into teaching and learning for a variety of reasons such as: promoting student engagement, teaching 21st century skills, as best teaching practice, to stay current, for hands-on interactive learning, to vary instructional methods, to perform labs and demonstrations, and for research and communication (Hakverdi-Can & Dana; 2012; Hechter & Vermette, 2012a). Yet, "administrative, technological, organizational, and philosophical barriers exist that seriously hinder the effective implementation of technology into classroom teaching and learning" (Hechter & Vermtte, 2012b). In a review of extant literature, these factors are referred to as first-, second-, and third-order barriers to change which impede technology integration in classrooms (Ertmer, 1999; Ertmer, 2005; Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur & Sendurur, 2012; Hew & Brush, 2007; Ottenbreit-Leftwich, Glazewski, Newby & Ertmer, 2010; Tsai & Chai, 2012; Wachira & Keengwe, 2011). Applied across a variety of teaching disciplines, teachers require access to technology, time, training, and support (Ertmer, 1999, p. 56; Wachira & Keengwe, 2011), as well as pedagogical beliefs and values that positively support technology integration including “teacher-student roles, curricular emphases, and assessment practices” (Ertmer, 1999, p. 58); and finally, student-centered, constructivist or pluralistic pedagogies (Becker, 2000; Harris, 2005; Seimears, Graves, Schroyer & Staver, 2012) that encourage and enhance design thinking in teachers (Tsai & Chai, 2012), in order to achieve successful technology integration in K-12 classrooms.

It is truly unfortunate that despite the availability of support, literature, and community, inservice teachers still find it difficult to effectively integrate modern technology into their classrooms (Hechter & Vermette, 2012b). This may be in part due to “Web 2.0’s high complexity, low received relative advantage over current educational practice, insufficient chances to observe or try the technologies for educational purposes and incongruence with current pedagogical practices” (Hughes, Guion, Bruce, Horton & Prescott, 2011, p.58).

Inservice teachers who possess the knowledge, skills, abilities, dispositions, creativity, and desire to integrate technology into classroom teaching and learning encounter barriers, are able to employ innovative and critical problem-solving abilities to structure lessons with technological variety using what is at hand, and what can be obtained or accessed (Hakverdi-Can & Dana; 2012; Hechter & Vermette, 2012b; Hew & Brush, 2007; Wachira & Keengwe, 2011). Developing a knowledge base of these attributes allows teachers the ability to reach students with digital fluency (Wang, Myers & Sundaram, 2012) by engaging them with timely and relevant curriculum in a manner that promotes best teaching practice for integrating educational technologies (Harris, 2005; Hughes, 2005; Ottenbreit-Leftwich et al., 2010). Educational technologies encompass a wide range of applications, including student-driven media that are placed in students’ hands, for student use, and to promote student interactions (Hechter & Vermette, 2012a). Teachers today need to develop current working knowledge of a variety of technologies, as well as the knowledge to appropriately match and apply technologies to relevant content in the classroom, to reach digitally fluent students (Wang et al., 2012).

Integrated versus Isolated Technology Courses in Teacher Education Programs

Teacher education programs are experiencing reform-based transformations as resources, attract-ability for prospective students, and efficiency continue to become increasingly important factors in program development and implementation. A key aspect of this transformation, and of key relevance to this article, is the nature of teachers' technology instruction. Due to mounting calls for efficiency and enhanced programming, teacher educational institutions are pursuing the idealism of a technology enriched framework relevant to each curricular discipline to be integrated into curriculum, teaching and learning courses (Hughes, 2005), also known as 'methods courses'.

In typical teacher education programs, preservice teachers enroll in a methods course often after taking independent courses in discipline area content, pedagogical theory, and technology for teaching. These courses tend to work in isolation as opposed to an interrelated entity (Hughes, 2005). Moving instruction from isolated to interrelated contexts can better help teachers conceptualize and understand technology as part of their teaching and learning sequences (Hughes, 2005).

Successful integration of technology in the classroom is dependent on teachers' beliefs, values, and attitudes regarding the perceived relevance of the technology to student learning (Ertmer, 2005; Ertmer et al., 2012; Hughes, 2005; Ottenbreit-Leftwich et al., 2010). We acknowledge the disparate nature of espoused and enacted beliefs in technology integration in terms of the influence on technology selection, and on the impact of technology in teaching and learning (Ertmer et al., 2012). Specific to our interpretation, Grandgenett (2008) identified technology based pedagogical strategies that teachers can use to locate 'where' their students are conceptually, 'what' students next learning phase would be in the instructional sequence, and ‘how’ teachers envision student engagement and progression throughout the classroom experiences.

Hughes et al. (2011) suggested that strategies that capitalize on teachers’ “reflection, interpretation, and intervention” (p. 58) will help connect teachers’ beliefs, knowledge, skills, and abilities about technology integration into their pedagogical practices. In addition, Hughes (2005) suggested that in order for technologies to be used in effective ways in classroom teaching and learning, teachers benefit from understanding the critical relationship between subject-specific technology use, pedagogical approaches, and the potential for improved curricular understanding. We support this notion, as it is clearly linked to a technology enriched, content-specific, pedagogical framework in that it encompasses progressive and iterative uses of technologies to promote classroom teaching and learning.

Theoretical Framework

Technology, Pedagogy and Content Knowledge (TPCK) Model

The theoretical framework guiding this paper is the TPCK model (Mishra & Koehler, 2006). TPCK, at its most foundational level, is the intersection between the development of knowledge of subject matter (content), with the development of technology, and the knowledge of teaching and learning (pedagogy). This framework, on a more global scale, combines appropriately selected technology with content-based learning experiences and pedagogical approaches.

Within Mishra and Koehler’s (2006) TPCK graphic (Figure 1), the overlapping of the discrete knowledge bases is obvious, as it is the centric overlap of all three. It is this area, when teachers can expertly understand and integrate all three knowledge bases, that the TPCK model postulates high quality and effective integration of technology, pedagogy and content as part of the teaching and learning experience. As Foulger, Wetzel, Buss, and Lindsay (2011) contend, while teacher educators may be well versed in the pedagogies associated with specific disciplines, and may teach using

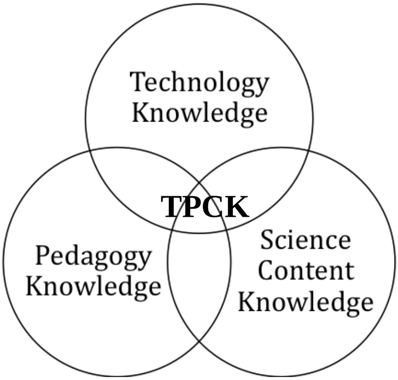

Figure 1. TPCK model (Mishra and Koehler, 2006)

modern technology; these individuals may not be experts in how to teach with technology. It is this distinction, however subtle it may be, where the nature of deconstructing the TPCK theoretical model into usable and practical applications becomes increasingly valuable.

Applying the TPCK Model in Preservice and Inservice Teacher Education

Technology, pedagogy, and content-specific knowledge should be blended together to improve teaching and learning (Graham et al., 2009; Hakverdi-Can & Dana, 2012; Neiss, 2005). The key aspects of this premise come into focus with Mishra and Koehler's (2006) TPCK model. Strongly supported in the literature, TPCK can be adopted into all learning levels and curricular areas (Koehler, 2011). This model provides the framework to identify and connect the inter-relationships between technology, pedagogy, and content towards developing modern teachers' effective and appropriate use of educational technologies in their teaching (Mishra & Koehler, 2006). Prior to the formal construction of TPCK model, Angeli and Valanides (2005, p.155) argued that the application of technological, pedagogical, and content knowledge principles should be understood under the broad contexts of school environments, individual teachers' previous experiences, and epistemological beliefs about teaching and learning. "In summary, previous research suggests that there is a need to address the issue of TPCK for successful technology integration, and personal beliefs about pedagogy and technology should be considered for the development of TPCK." (So & Kim, 2009, p. 105).

We agree with Bos (2011) that as a teacher's cognitive complexity, specifically in terms of skills and strategies appropriate for the 21st century classroom (Geer & Sweeney, 2012), is developed towards integrating modern technology, the greater the value of the construct. Ironically, perhaps, in light of the principles of complexity in education (Doll, Fleener, Trueit & St. Julien, 2005; Gough, 2012); we advocate for a reductionist approach to deconstructing the TPCK model to best identify and illuminate TPCK's relationships and connections toward pragmatic applications for preservice and inservice teachers. This deconstruction involves recognition of the intermediate steps of conceptually understanding the TPCK model, which we refer to as the 'spaces between'.

The Spaces Between

In this paper we identify the 'spaces between' the TPCK model as the places where only two knowledge bases intersect, and, using science content as our example, these are Technological Pedagogical Knowledge (TPK), Technological Science Content Knowledge (TSCK), and Pedagogical Science Content Knowledge (PSCK) (Figure 2). We refer to these as 'dual-overlapping' areas throughout this interpretation. These dual-overlapping areas are of substantial importance in terms of understanding how the various aspects of the TPCK model interact with one another. Research continues to show that novice teachers need to move from beginning behaviours and understandings located in the three discrete areas of Technology Knowledge (TK), Science Content Knowledge (SCK), and Pedagogical Knowledge (PK); through the intermediate understandings of TPK, TSCK, PSCK; towards an expert and integrated pedagogue (Hechter & Phyfe, 2010). As such, we contend that learning how to navigate the 'space between' areas should be a critical, and explicit step in teacher education.

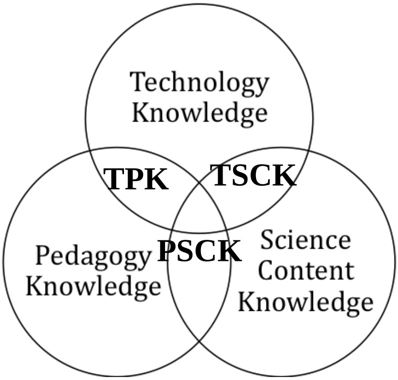

Figure 2. TPCK model showing spaces between (TPK, TSCK, PSCK)

While it is theoretically possible for preservice or inservice teachers to ascend the model to a full integration of the knowledge types without passing through the intermediate dual-overlapping steps, we believe this is a complicated trajectory. Explicitly designed lessons in science methods courses, for example, may be pivotal in helping move preservice teachers along the continuum from novice integration of these three framework elements to an expert level of full TPCK fusion. For us, this identifies the need to deconstruct, for theoretically reductive purposes, the TPCK model to assist teachers in moving through these initial steps to a greater understanding of the way that technology can be integrated in science education.

Connecting the Spaces Between to Standards in Science

Applicable to both inservice and preservice teachers, national and international standards for science content, teaching methodologies, and technology inclusion are clearly stated by several widely-recognized professional organizations. In the following paragraphs we connect standards for technology integration to both science content knowledge, as well as pedagogical knowledge.

Integrating technology into science content (TSCK) is not new to educational literature, policy, or curriculum. The new Australian Curriculum (ACARA, n.d.) places emphasis on integrating technology into the specific learning outcomes towards collecting, analyzing, and communicating evidence through inquiry as insight into the biological, physical and technological world. Further, the National Curriculum Board (2009) in Australia, identifies technology as complex social enterprise and a critical aspect for modern approaches to problem solving. In the United States, the National Science Education Standards (NRC, 1996, 2000) explicitly state that technology needs to be an integral part of the curriculum as well as the instructional process. Similarly, the International Society for Technology in Education (ISTE) encourages the integration of technology into the classroom, rather than using it as a stand-alone or add-on component. The ISTE posits that technologies need to become ‘‘an integral component or tool for learning and communications within the context of academic subject areas’’ (ISTE, 2000, p. 17). In addition, within our province in Canada, the provincial government’s education branch, Manitoba Education, created a policy-to-curriculum initiative designed to support inservice teachers towards the philosophical groundings of technology integration within education across the disciplines (Manitoba Education, n.d.), thereby supporting this notion.

Technological and pedagogical areas (TPK) have also gained importance in recent years. In the United States, technology integration teaching standards can be found in the Interstate New Teacher Assessment and Support Consortium Standards (InTASC) and the National Educational Technology Standards for Teachers (NETS-T). Despite these standards, guidelines, outcomes, and policies being prevalent and widely accepted, preservice and inservice teachers alike are still having a difficult time effectively integrating modern technology into their science classrooms (Hechter & Vermette, 2012b). “But, for technology to become an integral component or tool for learning, science preservice teachers must also develop an overarching conception of their subject matter with respect to technology and what it means to teach with technology” (Niess, 2005, p. 2). This sentiment encapsulates our thinking, and grounds this paper. As such, we suggest pragmatic ways to apply the TPCK framework, including its individual, dual-overlapping, and tertiary components through relative proportions and oscillations.

Relative Proportions

Planning for lessons, student experiences, and curricular units are complex activities that incorporate pedagogical philosophy and strategy, contextual dynamics of the individual classroom, and vision (Berliner, 1986). The vision required within our interpretation of TPCK, is aligning the purpose the lesson and instructional sequence, with the intended curricular or essential outcomes. For example, if a teacher plans to help students develop their data collection skills (PK), a teacher may focus an activity on using modern technology (TK) in a science inquiry-based investigation. In our interpretation, we would identify this as the dual overlapping area of technological-pedagogical, or TPK. In this case, the emphasis is clearly on the technology, and science content is the context by which the lesson is designed. Subsequently, there is a fluctuating relative proportion of the three discrete knowledge bases of TPCK, dependent on the nature and context of the activity. While we agree with the literature that supports having preservice teachers progress along the continuum from novice to expert levels of technology integration, it is our contention that time spent deconstructing the TPCK model into space between areas only strengthens a preservice teachers’ understanding of the subtleties of purposeful and appropriate technology integration into a science classroom.

As teachers plan for upcoming student learning experiences, different aspects of the overlapping sections of the TPCK model become more emphasized than others. As such, if the primary intended outcome of a lesson is the conceptual explanation of a difficult science phenomenon (SCK) through group collaboration (PK), this is a focus on PSCK. As such, the PSCK overlap is of greater relative proportion than either the TSCK or the TPK. If the next lesson is designed for each group to present their explanations to peers through modern means using a Prezi, an online version of Powerpoint (TK), the focus of this lesson would then include the technology piece in a higher proportion. In these examples, when visualized using the TPCK model, not only are the lessons focused on the spaces between, instead of the triple overlapping area, but those dual overlapping sections expand and contract, or oscillate in the overall model's framework, not remaining in the equal proportions as suggested by the visual model of Mishra and Koehler (2006).

Oscillations

Classroom activities, in spite of how detailed they are planned, tend to ebb and flow. In this rhythm, teachers make instantaneous decisions to pursue new or modified avenues of teaching and learning, while abandoning others. In these moments, a teacher may realize that the plan to focus an activity on a technological application of a science phenomenon may in fact turn into a group discussion about the nature of science. Here, the technological knowledge base retreats in importance, and the pedagogical knowledge base emerges with significance. As such, the originally organized relative proportions of each knowledge base are replaced by a new plan. The knowledge bases do not disappear, but theoretically oscillate in importance in a given moment.

A practical example of this is if a teacher were to initiate a learning experience by displaying an attention-grabbing image (or object, experiment, phrase, story) of the celestial sky to the class (PSCK). In an attempt to understand more about the image, the teacher then organizes the class to use relevant online astronomy based simulation software, such as Stellarium (2012), to explore where and when this image was taken, and to allow students to draw some conclusions about what they are seeing in the image. This stage of the lesson focuses on TSCK aspect, as students begin to work with the technology in order to develop deeper conceptual understanding about what they are seeing in the image. A discussion follows about what the technology helped them learn, and the value of using the technology in the lesson (TPK). Here we see that in different stages throughout the lesson, each dual-overlapping aspect of the TPCK model became more and then less important as the lesson progressed.

While full TPCK integration is a desired outcome for effectively teaching and learning with technology, these areas tend to manifest throughout a lesson in relative proportions depending on the teachers' pedagogical goals and their actual classroom practices. In summary, our interpretation of the TPCK model suggests that in specific moments in the instructional and learning sequence, different dual overlapping sections become more prevalent and focused than others; thus, their appearance in the lesson oscillates to the cadence of the given context.

Future Research

The deliberate deconstruction of the TPCK model in the science methods class can create a deeper awareness and understanding of the nature of integrating technology with pedagogical sequences and science curricular content. As a critical part of teacher education programs, future research will include how preservice teachers come to understand the nature of the intertwined relationships of the discrete knowledge bases. Further, it is hoped that research will capture the actual progression of preservice teachers along the path from novice to expert levels of technology integration. Analyzing movement along the continuum will focus on how the TPCK model is not a static entity, but is dynamic and ever-changing. This research will inform professional development models and content for inservice teachers, as well as school division administrations.

Conclusions

Preservice and inservice teachers require support to effectively integrate educational technologies into the science classroom through a thorough deconstruction and conceptual understanding of all aspects of the TPCK model. Carefully planned science content lessons may include deliberate aspects of each dual-overlapping segment of TPCK (specifically TPK, TSCK, and PSCK), in a manner that suggests that teachers are developing TPCK awareness.

With more complex thinking and ability, teachers are able to reduce the TPCK model to its constituents and then plan, create, and deliver excellent student learning activities. While teachers move along the technology integration continuum from novice to expert, they will encounter the intersection of the three tenets of TPCK in oscillating amounts according to the relative proportions of each of these aspects throughout the various stages of the planning and implementation of their specific lessons. Concerned with the fluidity of each lesson, different dual-overlapping segments will become more and less important as the lesson progresses. It is in this recognition that we suggest that TPCK is not a static goal that emanates effective technology integration, rather, it is an oscillating variable, moving fluidly within the intersections of technology and science education.

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