TPACK: AN EMERGING RESEARCH AND DEVELOPMENT TOOL FOR TEACHER EDUCATORS

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ABSTRACT
TPACK (technological pedagogical content knowledge) has emerged as a clear and useful construct for researchers working to understand technology integration in learning and teaching. Whereas first generation TPACK work focused upon explaining and interpreting the construct, TPACK has now entered a second generation where the focus is upon using the construct in both research and development projects. In this paper, the TPACK construct is defined and several current research and development projects that use the TPACK framework are described. The strength of the TPACK framework in research and evaluation work in technology integration is discussed, along with future directions for this work.

INTRODUCTION

TPACK (technological pedagogical content knowledge) has emerged as a clear and useful framework for researchers working to understand technology integration in learning and teaching. Building on Shulman's (1986) idea of PCK, Mishra and Koehler (2006) added technology to PCK and described the resulting TPCK as the interweaving of technology, pedagogy, and content. Renamed TPACK (technological pedagogical content knowledge), the combination of subject content, pedagogical, and technological knowledge "form an integrated whole, a 'Total PACKage'" (Thompson & Mishra, 2008, p. 38). TPACK is a framework that focuses on the complex interactions between a teacher's knowledge of content (CK), pedagogy (PK), and technology (TK). The combination of technology with pedagogy in a particular subject area must take into account the dynamic intersections such as TPK (technological pedagogical knowledge), PCK (pedagogical content knowledge), and TCK (technological content knowledge). A teacher who can navigate between these interrelations acts as an expert who is different than a sole subject matter, pedagogy, or technology expert (Mishra & Koehler 2006).

TPACK explains that teachers are able to make sensible and creative choices in their use of technology in the classrooms. Whereas first generation TPACK work focused upon providing a theoretically grounded definition of TPACK (Mishra & Koehler, 2006), explaining and interpreting the construct and discussing characteristics of TPACK and TPACK in different content areas (AACE, 2008), TPACK has now entered a second generation in which the focus is upon using the construct in both research and development projects (Thompson & Schmidt, 2010). In this paper a review is presented followed by a definition of the TPACK construct and then illustrations of several recent exemplary current research and development projects that use TPACK as a framework. The paper concludes with a discussion of promising future directions for this work.

TPACK (Technological Pedagogical Content Knowledge)

With the emergence of digital technologies, technology has become an indispensible part of educators' and students' lives, changing the way teachers and students interact and learn in a technology-rich environment. Early attempts at technology integration treated technology as an entity that needed to be learned separately from pedagogy and content. This notion was reflected in preservice and inservice teacher education programs, which maintained isolated technology courses or workshops that focused upon technologies separate from content and pedagogies in teaching contexts. Recently, however, arguing a need for a situated teacher knowledge required for effective technology integration, researchers have started using TPACK as a framework for designing and developing programs to equip teachers with a more interconnected knowledge that is concentrated on student

learning in various content areas—technological pedagogical content knowledge (American Association of Colleges of Teacher Education, Committee on Innovation and Technology, 2008).
TPACK is a theoretical framework for understanding teacher knowledge required for effective technology integration (Mishra & Koehler, 2006). The TPACK framework was proposed in order to emphasize the need to situate technology knowledge within content and pedagogical knowledge. TPACK considers teachers' knowledge as complex and multifaceted, critiquing techno-centric approaches that focus on the attainment of technology skills separate from pedagogy and content.

TPACK acts as a useful framework for thinking about what knowledge teachers must have to integrate technology into teaching and how they might develop this knowledge. It recognizes the unique and interactive roles that content, technology, and pedagogy play in authentic teaching and learning environments and suggests the consideration of "an emergent form of knowledge" that goes beyond content, technology, and pedagogy alone (Mishra & Koehler, 2006, p. 1028). Seven components (see Figure 1) are included in the TPACK framework. They are defined as:

1. Technology knowledge (TK): Knowledge about various technologies, ranging from low-tech technologies, such as pencil and paper, to digital technologies, such as the Internet, digital video, interactive whiteboards, and software programs.
2. Content knowledge (CK): Knowledge about the actual subject matter that teachers must know about to teach.
3. Pedagogical knowledge (PK): Knowledge about the methods and processes of teaching such as classroom management, assessment, lesson plan development, and student learning.
4. Pedagogical content knowledge (PCK): Knowledge that deals with the teaching process (Shulman, 1986). Pedagogical content knowledge is different for various content areas, as it blends both content and pedagogy with the goal to develop better teaching practices in the content areas.
5. Technological content knowledge (TCK): Knowledge of how technology can create new representations for specific content.
6. Technological pedagogical knowledge (TPK): Knowledge of how various technologies can be used in teaching.
7. Technological pedagogical content knowledge (TPACK): Knowledge required by teachers for integrating technology into their teaching in any content area. Teachers, who have TPACK, act with an intuitive understanding of the complex interplay between the three basic components of knowledge (CK, PK, TK).

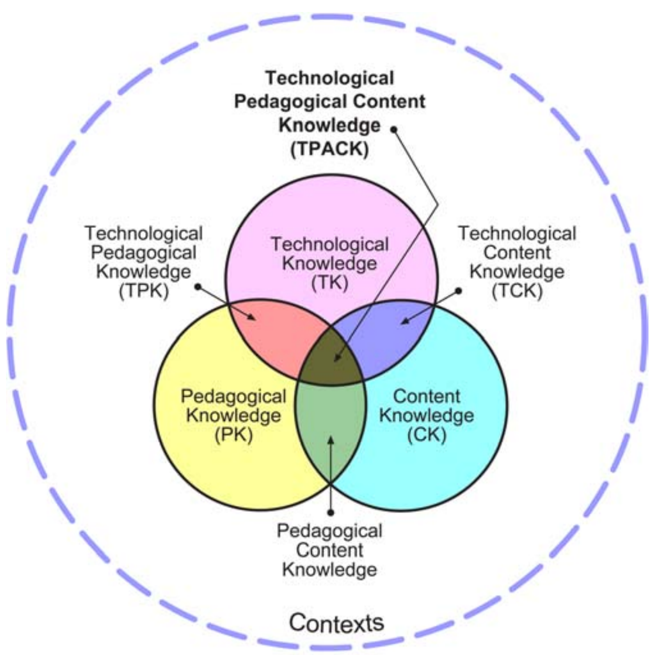

Figure 1: The components of the TPACK framework (graphic from TPCK - Technological Pedagogical Content Knowledge, 2010).

TPACK Survey Research

Building on a history of using survey methods to assess teachers' levels of technology integration, researchers have created survey instruments that assess preservice teachers' and in-service teachers' levels of TPACK. Existing surveys have tended to focus on teachers' self-assessment of their levels of technology use (e.g., Keller, Bonk, & Hew, 2005; Knezek & Christiansen, 2004). Following the development of the TPACK framework, researchers began to work on the problem of assessing both preservice and inservice teachers' levels of TPACK (Archambault & Crippen, 2009; Koehler & Mishra, 2005). Using the TPACK framework to guide the research design, Schmidt, Baran, Thompson, Mishra, Koehler, and Shin (2009) developed an instrument with the purpose of measuring preservice teachers' self-assessment of their TPACK and related knowledge domains included in the framework.

The purpose of developing the instrument in the Schmidt et al. (2009) study was to use it to assess the development of TPACK in an introductory preservice teacher technology course in a longitudinal research study. Data are being gathered at specific checkpoints during the preservice teachers' preparation program. As part of this study, preservice teachers are being tracked during their teacher education program and asked to complete the survey after completing their instructional technology course, methodology courses (e.g., literacy, science, social studies, mathematics) and student teaching. Additional qualitative research studies are also being conducted to examine how these same preservice teachers demonstrate TPACK-related tendencies in PreK–6 classrooms during practicum and student teaching experiences. The research group has currently completed the first steps in the 3- to 5-year longitudinal research project by collecting the survey data from preservice teachers who took the technology integration course. These findings of preservice teacher classroom behavior will be compared with how they respond to the survey at various times during their preparation program.

The results reported below use the data gathered at the beginning and end of two semesters (Fall 2008 and Spring 2009) when about 180 preservice teachers were enrolled in an introductory instructional technology course. This stage of the research project, Phase 2, included two major goals: to continue the validation of an instrument that would help in predicting preservice teachers' classroom behaviors related to TPACK and to collect baseline data to provide a comparison for assessing preservice teachers' understanding and application of TPACK during their preparation program. Schmidt et al. (2009) provided a description of the instrument's initial development and validation process in detail (Phase 1 of instrument validation).

Overall reporting of the results indicated there were significant increases between the respondents' pre- and posttest means for all seven TPACK subscales (see Table 1). The differences were substantial for TK, PK, TCK, TPK and TPACK subscales as the effect sizes were greater than 0.5. The remaining four TPACK subscales all addressed participants' understanding of content knowledge (in literacy, math, science and social studies).

Table 1: T-test results for pre- and post-test mean score responses for TPACK subscales

TPACK subscale	Pretest: *M* (*SD*)	Posttest: *M* (*SD*)	Matched-pair *t* (*df* = 179)	*p* value	Cohen's *d*
TK (6 items)	3.52 (0.66)	3.85 (0.58)	8.95	<.001***	.67
CK					
Mathematics (3 items)	3.64 (0.68)	3.82 (0.69)	4.06	<.001***	.30
Literacy (3 items)	3.86 (0.54)	4.07 (0.48)	5.64	<.001***	.42
Science (3 items)	3.60 (0.61)	3.74 (0.55)	3.80	<.001***	.28
Social Studies (3 items)	3.74 (0.66)	3.90 (0.61)	3.75	<.001***	.28
PK (7 items)	3.71 (0.52)	4.04 (0.44)	9.71	<.001***	.72
PCK (4 items)	3.64 (0.61)	3.88 (0.57)	5.29	<.001***	.39
TCK (4 items)	3.20 (0.74)	4.08 (0.51)	14.39	<.001***	1.07
TPK (9 items)	3.85 (0.51)	4.23 (0.45)	9.06	<.001***	.67
TPACK (4 items)	3.43 (0.69)	4.03 (0.54)	10.77	<.001***	.80

****p* < .001.

TPACK has the potential to provide a new framework for developing learning experiences for future teachers. Through developing and using the TPACK instrument, work to operationalize the TPACK concept for teacher educators and preservice teachers is progressing. Using this instrument and related classroom behavior measures, feedback is provided to both students and teacher educators on the impact of teacher education experiences in the development of TPACK. Ultimately, the assessment of TPACK can provide information that will help design TPACK learning experiences throughout teacher education programs.

Currently, work in Taiwan is expanding the TPACK survey work to answer questions about effective technology use in teacher education programs and the impact of technology modeling use in the teacher preparation stage on teachers' TPACK development when they enter their professional teaching career.

TPACK as a Tool for Modeling Research

The study conducted in Taiwan examined the relationship between the degree of technology modeling uses during the teacher preparation stage and the development of early childhood teachers' TPACK in Taiwan. In this study, Schmidt et al.'s (2009)' TPACK survey instrument was translated and adapted to fit into the existing context for early childhood teachers in Taiwan. After a rigorous pilot test, Chinese TPACK questionnaire items with good validity and reliability were developed (Chuang & Ho, 2010). The purpose was to explore the relationship between five technology modeling uses in early childhood preservice teacher education program and the early childhood teachers' present TPACK knowledge. A wide range of technology modeling uses was incorporated based on related literature, the specific situation of technology use in higher education in Taiwan, and consultation from the field experts. Five items were formed to be included in the technology use modeling section in the survey instrument. These items are: (a) the use of information technology (IT) hardware and software in teaching and learning, (b) the use of digital materials and multimedia educational software, (c) the use of online course platforms, (d) the use of online assessment, and (e) the use of CMC (computer-mediated communication) tools to facilitate interactions among learners and instructors.

Quantitative data were collected from a sample of 335 inservice early childhood teachers in Taiwan. Follow-up interviews were also conducted with 5 survey respondents. The interview protocols were developed based on the five technology modeling uses to gather richer and more detailed responses, probe for further information, and clarify any confusing issues regarding the five technology modeling uses in early childhood teacher education. Pearson correlation and multiple stepwise regression analyses were conducted with the early childhood teachers' self-assessed TPACK as the dependent variable and the five technology modeling uses by the teacher educators as the potential predictors. Qualitative data were transcribed and analyzed by the constant comparative method (Lincoln & Guba, 1985). First, the interview transcriptions were coded. Then the coded segments were constantly compared within the interview contents, and finally, the concepts and themes were compared across interviews until recurring themes emerged.

Quantitative data analysis results showed that the extent of the five technology modeling uses during the teacher preparation stage had a mean of 3.57 (*SD* = 0.74) on a 5-point Likert-type scale, indicating middle level exposure to technology use modeled by teacher educators for this group of early childhood teacher respondents. Furthermore, respondents' self-assessed TPACK and the extent of the five technology modeling uses during the teacher preparation stage was significantly correlated at the 0.01 level with the Pearson product–moment correlation (*r*) ranging from .4 to .628. In addition, a summary of stepwise regression results indicated that two technology modeling uses were significant predictors of the TPACK measure ($p < .001$). These two variables were (a) the use of CMC tools, such as e-mail, blogs, and web discussion forums, to facilitate interactions among learners and instructors and (b) the use of digital materials and multimedia educational software. The strongest predictor was the use of CMC, such as e-mail, blogs, and web discussion forums to facilitate interactions among learners, which accounted for 33.1% of the variance (see Table 2).

Table 2: Summary of stepwise regression results for TPACK measures

Model	*R*	R^2	*Adjusted* R^2	*F*	*B*	Beta (β)
1	.575[a]	.331	.329	164.480***	2.415	.389
2	.605[b]	.366	.362	95.803***	1.693	.265

[a]Predicator (constant): the use of CMC tools. [b]Predicator (constant): the use of CMC tools, the use of digital materials and multimedia educational software; [c]Dependent measures: TPACK.
****p* < .001.

A careful examination of the qualitative data identified major themes that illustrate the technology modeling uses during early childhood teachers' teacher education. Those themes include the transfer of the modeling experiences to teachers' current teaching practice and reflection on the selection of appropriate technology uses for young children.

Transfer of the Modeling Experiences to Teachers' Current Teaching Practice

The social learning theory of Bandura (1977) emphasizes the importance of observing and modeling the behaviors, attitudes, and emotional reactions of others. Specifically, it focuses on the learning that occurs within a social context and considers that people learn from one another. Efforts to model how these technology-enhanced modeling lessons are used to support instructional objectives in the teacher preparation stage may result in stronger beliefs about the value of technology for teaching and learning. In turn, these stronger beliefs are more likely to translate into more frequent use of technology once a preservice teacher enters the profession. For instance, in this study, teachers mentioned that they learned to use digital picture books available on the web. One of the teachers indicated how she used to think that the Internet was for only older children and teenagers. However, when her professor guided them around several websites containing digital picture books with vivid animations and narrations, she witnessed how children of different learning styles attentively reacted to the multimedia digital picture books in their learning preferences. As a result, her professor's model had a big impact on the way she thinks about "reading" to young children. Another teacher recalled that she was really inspired by one of the teaching demonstrations on the web in one of her courses in the teacher education program where the teacher collaborated with the students to create a digital class book introducing vehicles. She has tried that idea several times in her own class with young children and with different topics.

Reflection on the Selection of Appropriate Technology Uses for Young Children

Teachers tend to teach the way they were taught. Teachers' attitude and behavior towards technology use in educational environments are highly influenced by their experiences regarding the perceived benefits of the adoption of educational technology use. Research has emphasized the importance of teacher education faculty modeling use of technology in the teacher preparation programs for the development of future teachers' confidence, attitudes, and adoption of technological innovations in the K–12 classroom (Adamy & Boulmetis, 2005; Pope, Hare, & Howard, 2002). In social learning theory, Bandura (1977) categorized the influences on human social behavior as personal, environmental, and behavioral factors. According to this theory, modeling serves an informational function by which observers cognitively organize and rehearse the observed movements and later translate the encoded information into action. As such, PowerPoint is one example. According to the interview data, PowerPoint is probably the most commonly used software application in the college classroom. Several of the early childhood teachers mentioned that they know that the way PowerPoint is used at college should be different from that in the kindergarten classroom. One said that the purpose of PowerPoint at the college level is to highlight key points of text in a lecture; however, in her own case she used PowerPoint to provide multimedia visual aids. She indicated,

> Graphics and illustrations are critical components at the stage of child development. I will not use PowerPoint the way I experienced at college. However, those experiences [at college] make me think how I can use them most appropriately for young children.

Others also commented that observing the professors' use of technology in the classroom was a starting point for them to reflect on the use of technology with young children in their classroom.

The teachers' reflection on the use of PowerPoint with young children is an example of a meaningful level of TPACK in early childhood classroom and also illustrates that teachers' professional development in technology integration should go beyond traditional technological skills. To teach with technology emphasizes the rich connections between content, pedagogy, and technology in a context. The professor's modeling of the use of PowerPoint provoked thoughts that showed a shift towards developing TPACK for early childhood teachers.

Results from this study reinforce and validate the significance of the effect of technology modeling in the teacher preparation stage. In addition, it echoed findings from previous research from Preparing Tomorrow Teachers to Use Technology (PT3) grant projects on the positive effects of modeling in technology use and integration in teacher preparation courses for preservice teachers' future use of technology in their professional career in K–12 schools (Adamy & Boulmetis, 2005; Casey & Casey, 2004).

TPACK in Development Work

The TPACK framework currently is being used in several projects aimed at improving technology integration work, both in K–12 classrooms and in teacher education programs. The framework provides a useful planning tool for work with faculty members and teachers in the area of technology integration. Whereas earlier faculty and teacher development work in the area of technology tended to focus upon learning the technology, the TPACK framework provides a structure to organize the development work around pedagogy and content as well as the technology. Harris, Mishra, and Koehler (2009) articulated:

> Typical approaches to technology-related professional development are based on the 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. (p. 402)

In one of the most widely known development initiatives, researchers are using an activity-type approach to use TPACK to help teachers effectively integrate technology into their particular content area (Harris & Hofer, 2009). The focus of the research is upon teacher planning, and it encourages teachers to focus upon the content of their lessons as the starting point for technology integration. The activity-type work includes careful descriptions of the major activity types teachers use in each of the major content areas. Activity types focus upon what students will be doing in a lesson and include a wide range of activities such as role playing, answering questions, or taking a field trip. For their work, Harris and Hofer have created taxonomies of activity types in different content areas. Each of the activity types is then analyzed in terms of potential technology tools that might prove useful within that activity type (Harris et al., 2009). Teachers are encouraged to plan by beginning with content goals for instruction and then moving to activity types that will support these goals. Only after these decisions are made does technology enter the picture. More information and related articles about this innovative approach can be found at the *Welcome to the Learning Activity Types Wiki!* (n.d.) website.

A second practitioner-oriented approach to TPACK comes from the GeoThentic Project (2008), a National Geographic-sponsored project based in TPACK that creates opportunities for students and teachers to use geo-spatial technologies to solve complex and authentic problems within an online environment. Teacher TPACK assessment and development are integral parts of this project (Doering, Veletsianos, Scharber, & Miller, 2009).

At Arizona State University, researchers have created a faculty development program based in TPACK that helps faculty design uses of Web 2.0 and social networking capabilities for their teacher education courses. Results from this work suggest that faculty members appreciate the focus upon content and pedagogy, as well as technology, and that in some cases, faculty are altering their content and/or pedagogy as a result of the affordances of the technology (Archambault, Wetzel, Foulger, & Williams, 2010). The TPACK framework for this work has helped move the focus from using social networking tools to designing uses of social networking tools that enhance content and pedagogy.

At Iowa State University, TPACK is used as the framework for the introductory technology course taken by all preservice teachers. This course has been taught in the preservice teacher education program at Iowa State University for more than 25 years. In the early years, the course focused on teaching preservice teachers to use computers and computer-related technologies. In recent years, the focus has changed to that of helping preservice teachers design and implement content-based lessons and units using technology. Students become skilled at identifying the pedagogy and content they will include in a lesson and focus upon ways technology can provide affordances for different contents and pedagogies.

Similarly, some K–12 school districts in the United States are finding the TPACK framework useful for designing and structuring their technology integration programs. One particularly interesting piece of news is that San Diego Unified School District has recently adopted TPACK in their 5-year technology plan (Devaney, 2009).

CONCLUSIONS

The enthusiasm among both researchers and practitioners for the TPACK framework has been very strong in the United States. The framework has provided a valuable tool, both for designing teacher education experiences and for assessing teacher knowledge in the area of technology integration. The TPACK survey described in this paper provides a means for measuring teachers' self-assessed TPACK and is proving to be a valuable tool for researchers interested in the development of TPACK in both inservice and preservice teachers. The TPACK survey is currently being translated into different languages and adopted to different teacher education contexts around the world. The interest of using TPACK framework and the TPACK survey for designing and assessing teacher knowledge in various international teacher education contexts is a clear indication of the world wide impact of TPACK as an emerging research and development tool for teacher educators.

The Taiwan project's use of a modified version of this survey to evaluate the effects of faculty modeling on preservice teachers demonstrates the use of the TPACK survey to provide information on the effectiveness of approaches to technology use in teacher education programs. The activity-types approach suggested by Judi Harris and Mark Hofer (2009) provides another compelling example of the usefulness of the TPACK framework for conceptualizing specific integration activities.

Future research with TPACK will include more work in the assessment area, with further refinement of the survey using larger, diverse samples and work to create classroom observation tools to assess teachers' TPACK in authentic classroom environments. Other work foreseen, similar to the Taiwan modeling work, will use TPACK assessment as a means to measure effects of interventions designed to improve teachers' uses of technology in classrooms.

In general, the TPACK framework has provided a means for educational technology researchers and practitioners to communicate more accurately and effectively about the work they are doing. In addition to the work to clarify the knowledge to be developed in preservice and inservice teachers, TPACK can bring clarity to the specific interventions in research and development projects and thus improve the ability to design and test powerful technology approaches.

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