



Designing TPACK-based course for preparing student teachers to teach science with technological pedagogical content knowledge

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Article Info

Article history:

Received 23 February 2018

Revised 10 May 2018

Accepted 19 July 2018

Available online 8 August 2018

Keywords:

mix-method,
teacher preparation program,
technological pedagogical content knowl-
edge (TPACK),
science,
student teacher

Abstract

The rapid technological advancement of the twenty-first century has transformed the ways in which we teach and learn. As a result, student teachers should be equipped to integrate technology into classroom practices, especially for specific subject matter. This research examined the effect of a Technological Pedagogical Content Knowledge (TPACK)-based course on 15 student teachers' TPACK. The research instruments included a questionnaire that covered the four components of TPACK, as well as lesson plans designed and implemented by the student teachers. Descriptive statistics and inductive analysis were used to analyze the data. The findings indicated that a basic understanding of technological knowledge was observed among the participants, rather than a more integrated knowledge of TPACK. The pedagogical knowledge component had a larger impact on student teachers' TPACK. The student teachers with low levels of PK were not able to make the pedagogy-technology linkage even if they had high TK. Moreover, the student teachers demonstrated a combination of technology, pedagogy, and content knowledge, rather than an integration of the three. Most student teachers used technology as a motivation booster, but no ICT-infused learning activities were used to encourage students to do scientific exploration or concept construction. The course should provide opportunities for student teachers to use technology to incorporate more inquiry experiences and more emphasis on PK revealed as a prerequisite for developing TPACK. Future studies related to science teachers' TPACK should develop a TPACK-based course that draws upon transformative viewpoints and inquiry-based instruction. Moreover, the technology course in teacher education programs should not only be conceptually integrated but also require enactment of technology-enhanced lessons.

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Introduction

The ability of the teachers to integrate technology into different teaching methods has become essential because of the rapid advancement of technology in the twenty-first century. This advancement has transformed ways in which people teach and learn in the school setting. Researchers have shown a growing interest in studying how teachers

incorporate technology into their teaching (Graham et al., 2009; Niess, 2005; Srisawasdi, 2014). Recent studies have shown that teachers need to have a good understanding of how technology can be coordinated with pedagogy and content knowledge in order to integrate technology effectively into classroom instruction (Gess-Newsome, 2002; Graham et al., 2009; Niess, 2005). This requires an expansion in our understanding of the teacher knowledge framework—that is, how teachers relate their pedagogical knowledge to their content knowledge or, as introduced by Shulman (1986), their pedagogical content knowledge

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Peer review under responsibility of Kasetsart University.

(PCK)—to a new framework that includes technological knowledge (TK), the so-called Technological Pedagogical Content Knowledge (TPACK) framework (Angeli & Valanides, 2009; Mishra & Koehler, 2006). According to Mishra and Koehler (2006), TPACK is an integration of technological, pedagogical, and content knowledge. These integrated forms of knowledge are PCK, technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPACK).

Many educational researchers recognize the broad appeal and potential of the TPACK framework, and it has been embraced as a theoretical basis for developing teachers' understanding of how to use technology constructively to support students' learning. However, there has been no consensus on the nature and development of TPACK among researchers and teacher educators. Several researches argue that the TPACK framework is not fully clear and that the boundaries among the constructs are fuzzy (Angeli & Valanides, 2009; Archambault & Barnett, 2010; Cox & Graham, 2009; Graham et al., 2009). Graham (2011) specifically argued three challenges related to the TPACK framework: the framework is complex, lacks theoretical clarity, and has undefined components. It is not, however, surprising that TPACK has come to be used by many researchers, from many and widely varied perspectives, and in very many and widely varied contexts. Graham et al. (2009) used the four TPACK constructs that involve technology (i.e., TK, TCK, TPK, and TPACK) to investigate science teachers' TPACK. TK represents technical skills (such as how to operate tools such as word processing, spreadsheet, and presentation programs). TPK represents the integration of technology with general pedagogical strategies (such as how to manage a technology-rich classroom, engage students with technology-oriented activities, and create useful presentations and assessments). TCK represents the knowledge of the technological tools and representations that are used by practitioners within a content discipline (such as the use of data collection and analysis tools, such as digital probes and spreadsheets, by scientists). Finally, TPACK, which is at the center of the model, represents the use of technology to support content-specific pedagogical strategies (such as the use of technology to support scientific inquiry in the classroom). The current study drew upon the framework of Graham et al. (2009) because it is commonly used for science teachers' PCK research, and the well-defined sub-components allowed us to fully understand teachers' TPACK.

Even though several researchers organized TPACK-based courses for student teachers, and they investigated teachers' development of TPACK (Chai, Koh, & Tsai, 2010; Graham et al., 2009), most pre-service teacher preparation programs offer instructional technology courses that focus on technology skills only (Hsu & Sharma, 2006). The instruction of technology skills alone is not sufficient to prepare student teachers for the pedagogical integration of technology (Mishra, Koehler, & Kereluil, 2009). This is because, even if student teachers know how to operate a piece of technology, they might

not know how to use it effectively to promote student learning (Graham et al., 2009). Moreover, a technology-enhanced lesson and the TPACK model—for example, the TPACK-based ID model (Lee & Kim, 2014) and the TPACK-COPR model (Jang & Chen, 2010)—are frequently used as a strategy to develop TPACK. However, there are few empirical studies that integrate technology into the PCK of science student teachers (Angeli & Valanides, 2009; Mishra & Koehler, 2006; Niess, 2005). Van Driel, Verloop, and de Vos (1998) mentioned that teaching experiences should be viewed as a major resource of PCK, with content knowledge (CK) and pedagogical knowledge (PK) being prerequisites. Teacher education programs should not only be conceptually integrated but also require authentic experiences. Despite the variety of TPACK models that have been proposed, only a few models consider both teachers' knowledge and teaching experiences (Bell, Maeng, & Binns, 2013; Jang & Chen, 2010). In the Thai context, there has been only a development course in computerized laboratory practices, including microcomputer-based laboratory (MBL) and computer simulations to develop student teachers' TPACK. The 5-year undergraduate physics teacher learns how to teach physics concepts through micro-teaching and peer-learning processes and designs lessons using MBL and computer simulations in the science classroom (Srisawasdi, 2014). The current study proposes a TPACK-based course that is knowledge- and experience-based. The results of this study can be used as a basis for designing a particular arrangement of courses to enhance student teachers' TPACK.

Research Question

How can a TPACK-based course in the teacher preparation program develop science student teachers' TPACK?

Methodology

This study of student teachers' TPACK used a mixed-methods approach (Creswell & Plano Clark, 2011). Both quantitative data and qualitative data were presented to describe the effect of the TPACK-based course on science student teachers' TPACK. Teachers' TPACK levels were commonly evaluated through self-reported TPACK survey ratings. Qualitative analysis of the student teachers' lesson plans was also used to better reveal what the teachers' thought and did based on their TPACK.

Participants and Course Design

Fifteen student teachers were enrolled in this study: two were preparing to teach physics, four to teach chemistry, and nine to teach biology in a high school science enrichment program. These three males and 12 females ranging in age from 25 to 27 years were enrolled in a 2-year Master of Teaching program at a large public university. These students had previously earned Bachelor of Science degrees from the Faculty of Science. They had deep knowledge in science and needed more knowledge of pedagogy, educational technology and integration of all

this knowledge. They were currently first-year students in the master's program. The teacher preparation program reviewed in this study was a two-year, graduate-level program that focused on the preparation of science teachers to teach science as inquiry. The students had completed mostly science content courses in their bachelor degree, and they took the science teaching method course and information and communications technology (ICT) course in the first year of the master's program. Furthermore, they completed a one-year practicum in their second year. During the first semester, the students took a science teaching method course focused on science inquiry pedagogy and biology/physics/chemistry content knowledge. The ICT course, implemented in the second semester, was designed to help student teachers develop the necessary knowledge and skills to integrate technology into science as an inquiry method. The current study followed the conceptualization of TPACK for science teachers introduced by [Graham et al. \(2009\)](#) to design the ICT course. The participants were involved in three phases of the course. In the first phase, activities for developing an understanding of the content of TPACK (CK, PK, TK,

PCK, TCK, TPK, TPACK) were implemented. For example, within the area of knowledge of the subject matter, participants explored the national curriculum and discussed the use of technology to teach different science topics within that curriculum. The development of TK was focused on in the second phase of the course, and at this point, several instructional technologies were presented to the students. These tools can be categorized into: 1) multimedia (graphics, audio, video, and 2D/3D animation); 2) presentation tools (such as Microsoft PowerPoint); 3) collaboration tools (such as Google Docs and YouTube); and 4) web 2.0 tools (such as WebQuest). Students were informed that they would not only learn about technology but also how to use technology in teaching activities. During the last phase of the course, aimed to enhance students' TPACK, students participated in examples of technology-enriched science activities; then each student teacher was encouraged to prepare a technology-enriched science lesson plan to teach for 1–2 periods in school, teach it, and reflect on the implementation. The structure of the TPACK-based course is shown in [Figure 1](#).

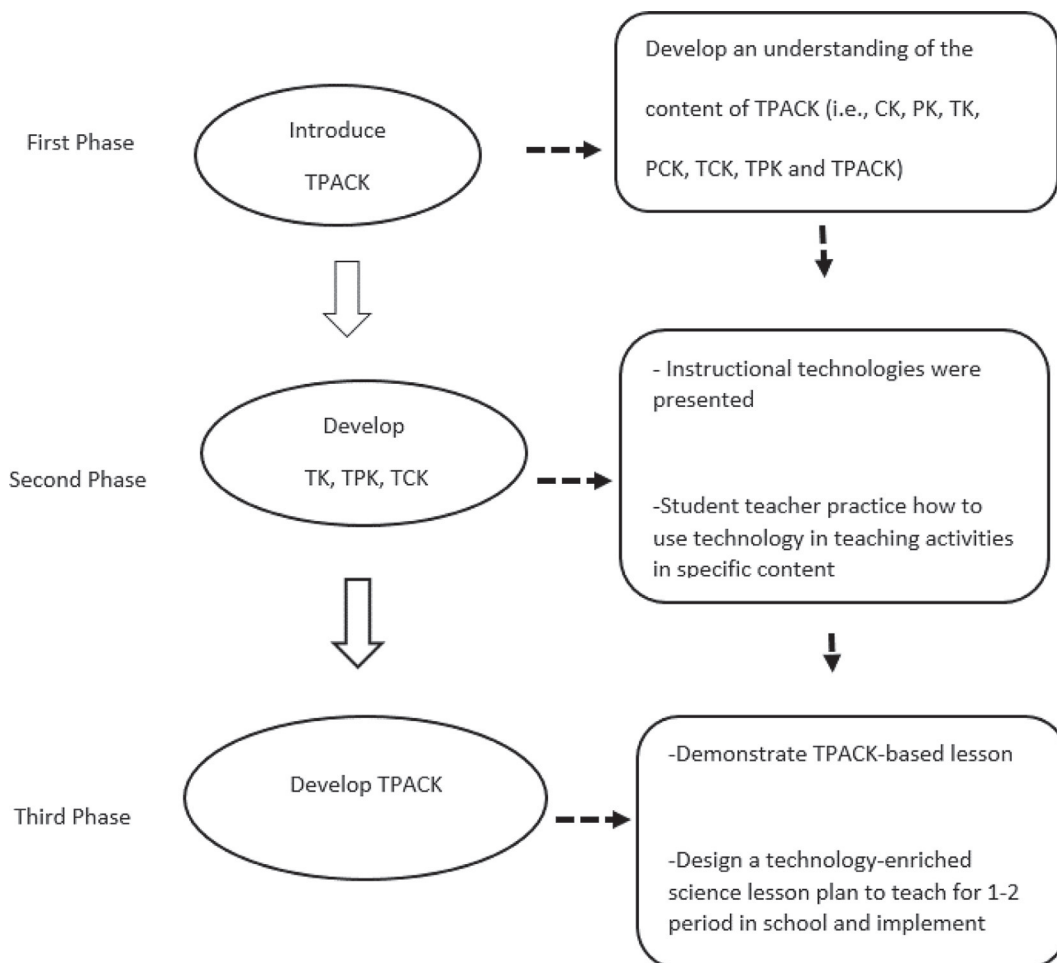


Figure 1 Structure of TPACK-based course

Data Collection and Analysis

The collection of data on the TPACK course attended by the student teachers was done through a self-reported TPACK survey. The questionnaire consisted of 26 items that were measured on a three-point rating scale that was designed by the researcher. Graham et al.'s (2009) survey provided a foundational structure for the survey used in this study, but items from other surveys were adopted to supplement items for assessing the four TPACK domains (TK, TCK, TPK, and TPACK). The questionnaire consisted of six TK items, six TPK items, six TCK items, and eight TPACK items. It was validated by three experts in science education. Based upon the feedback from experts, revision included moving some items between domains, wording of the items, and removing some items. The survey was administered to the student teachers at the end of the course, and participants were asked to respond to the questionnaire about their ability to use TPACK in science teaching. Then, the data from the questionnaire were analyzed and the mean score and standard deviation were calculated for each item.

Furthermore, the technology-enriched science lesson plans prepared and implemented by each participant in the last phase of the course were analyzed to determine how student teachers applied innovative teaching methods and strategies to their teaching practices. The data from the lesson plans were analyzed using inductive analysis to build patterns of meaning from the data (McMillan & Schumacher, 2001). Four phases, as described by McMillan and Schumacher, were employed for the analysis of the lesson plans: 1) employing continual discovery throughout the research in order to tentatively identify patterns; 2) categorizing and ordering data; 3) refining patterns by determining the trustworthiness of the data; and (4) synthesizing themes (Table 1).

Results

The presentation of the research findings relied mainly on the synthesized themes gained from the analysis of the lesson plans, which were then supported by the results of

the questionnaire. Table 2 shows the results of the questionnaire analysis, indicating that most participants had a lower ability to use TPACK than other knowledge components, with an average score of 2.28. The component in which the participants had the highest ability was TK, with an average score of 2.46.

Technology Knowledge (TK)

Theme. Use technology as a teaching tool to support instruction rather than as a tool for student learning.

The analysis of the content of lesson plans developed by participants showed that the use of technology can be categorized into three types: 1) as a method for teachers to search for learning media (such as images and videos) to use in the classroom; 2) as a tool for teachers to search for educational activities for students; and 3) as a resource or tool for searching for information for students. For example, in an introductory part of the lesson plan (engagement phase) about adaptation of organisms, a student teacher used pictures of the adaptation of an organism such as pictures of dogs sticking out their tongue or buffalos swimming in a mud puddle, to stimulate interest and ask questions “Why do animals behave in such a way?” (ST04). This was consistent with the self-reporting that the participants were most competent in searching and retrieving data from web-sites for their use (TK3), with an average score of 2.97,

Table 2

Mean score and standard deviation of science student teachers' ability to use TPACK in science teaching

(n = 15)		
Construct	$\bar{X}$	S.D.
Technology knowledge (TK)	2.46	0.48
Technological pedagogical knowledge (TPK)	2.39	0.46
Technological content knowledge (TCK)	2.45	0.52
Technological pedagogical and content knowledge (TPACK)	2.28	0.54

The findings from data and the lesson plans that each participant has designed and implemented in the classroom are detailed below

Table 1

Inductive analysis example of a lesson plan

Incident	Pattern	Themes
Showed images under microscope of pollen, stomata, nits, used dental floss, etc. and linked them to the study of the working principle of a microscope (ST02)	-Technology used for stimulating student interest -Technology used for present knowledge content	Use technology to stimulate student interest, Followed by experiences with hands-on activities, and deliver content
Used a video to show students images of different types of tissues followed by a PowerPoint presentation on the content and images to enhance students' knowledge about characteristics, types, and function of plant tissues (ST07)	Technology used to present knowledge content	
Watched video of baseball game with different batting energies and compared this to the collision of 2 atoms, and then doing an activity linked to collision theory in chemical reactions (ST06)	Use technology to stimulate student interest, followed by experiences with hands-on activities	
Showed images of different types of motion to stimulate student interest, followed by a laboratory session in which students measured the speed of objects using a ticker tape timer (ST03)	Using images to stimulate student interest and then do hands-on activity	

Lesson plan on rectilinear motion Engagement: teacher shows images of different types of motion including rectilinear motion, projectile motion, circular motion, and simple harmonic motion and asks students to select the images of rectilinear motion and then asks “What are the characteristics of rectilinear motion?” Exploration: teacher ask groups of students to do an experiment to measure the speed of objects using a ticker tape timer by observing the dots on the paper tape. If the tape is pulled through at a steady speed the dots remain the same distance apart (ST03).

Figure 2 Part of the lesson plan on rectilinear motion

but that the participants' ability to construct and use social media (TK6) and to use audio/video editing programs (TK2) were relatively low, with average scores of 1.87 and 2.00, respectively.

Technological Pedagogical Knowledge (TPK)

Theme. Use technology to stimulate student interest, followed by experiences with hands-on activities, and deliver content.

The analysis of the content of lesson plans developed by participants showed that the use of technology can be categorized into two types. First, technology can be used to stimulate interest and inquiries that help lead to scientific investigation. For example, a teacher might use of images of different types of motion to stimulate student interest, followed by a laboratory session in which students measured the speed of objects using a ticker tape timer as shown in part of the lesson plan in Figure 2.

Second, technology can be used to present knowledge content, such as using a video to show students images of different types of tissues followed by a PowerPoint presentation with content and images that will enhance students' knowledge and help them visualize more clearly after participating in the learning activities. This was consistent with the analysis of the questionnaire that the majority of participants used technology to enhance efficiency in presenting information to students (TPK5), with average score of 2.80, and to stimulate student interest and engage students in learning (TPK2), with average score of 2.47.

Technological Content Knowledge (TCK)

Theme. Use technology to help students visualize scientific concepts that are abstract or microscopic or macroscopic.

The analysis of the content of the lesson plans developed by participants showed that the main purpose for

using technology was to select and research learning media and activities that would help students to visualize concepts that are abstract or microscopic or macroscopic. For example, in a lesson on the law of segregation, a teacher could apply a construction of a sweet potato model (adapted from wordpress.com) to explain the law of segregation of pairs of genes. Students were assigned to create a model from sweet potato to display the phenotype of offspring by randomly picking alleles from parents (ST01). Another example was to design a lesson plan for the collision theory in chemical reactions, where a teacher could then search for images and videos of an occurrence at the macro level and compare it with the learning concept at the micro level, such as a video of a baseball games with different batting energies and orientations, which could help demonstrate the collision of two atoms (ST06). This was consistent with the self-reporting that the majority of participants used technology for searching, selecting, and retrieving information from online learning resources (TCK3), with an average score of 2.80. The study also showed that participants' ability to use technology to help students construct knowledge on their own by working collaboratively with their peers (TCK6) was the lowest, with an average score of 2.27. This was consistent with the data analysis of the lesson plans, which found that only one participant used a presentation program in presenting still images to increase student interest when introducing, explaining, or summarizing lesson content after the students had participated in the hands-on activities.

Technological Pedagogical Content Knowledge (TPACK)

Theme. Use technology as a motivation booster, but do not use ICT-infused learning activities for encouraging students to do scientific explorations or concept construction.

Although participants' self-reports showed the highest level of ability in selecting instructional methods and technology that are appropriate to their students for

science teaching (TPACK4), their technology and teaching method selection drew upon the specific science content that was being taught when designing their lesson plans. Their technology use can be categorized into two types. First, they used images or videos to stimulate student interest and to connect surrounding phenomena that can be observed in concrete forms to help students understand abstract concepts in the content. For example, a video about playing baseball was connected with the study of collision theory in chemical reactions. Second, they used a variety of images to stimulate student interest so they can compare differences, leading to the study of classification. For example, in a lesson plan on plant tissues designed by a student teacher (07), students were engaged with images of various plants and asked to compare them and guess which parts of plant tissue they were from. In the exploration phase, students then were asked to do the activity “Find a Family for Me,” by observing the characteristics they saw in each type of tissue, such as the shape, and note differences from neighboring cell groups. The students would then get into groups and present to the classroom.

Conclusions, Discussion, and Recommendations

In this study, the TPACK framework was used to design a TPACK-based course for developing student science teachers' TPACK. The course was consistent with Graham et al.'s (2009) framework, encompassing four constructs (TK, TPK, TCK, and TPACK). The results showed an obvious difference between student teachers' TK, TPK, TCK, and TPACK. The results showed that student teachers having a low competency in elements related to pedagogy resulted in a low TPACK level, which implied that PK had a strong impact on student teachers' TPACK. The inexperienced teachers who were weaker in pedagogical skills were less able to connect content, pedagogy, and technology (Niess, 2005). Teachers with low levels of PK were not able to make the pedagogy-technology linkage even if they had a high TK (Pierson, 2001). This framework revealed that the most effective process for science student teachers would be to move from PK to TPACK. In conclusion, this TPACK framework is a helpful model, as it can solve the recent problems in TPACK caused by the difficulty in separating out each of the domains—a difficulty that calls into question their existence in practice. Chai et al. (2010) found that their ICT course did not incorporate the fine distinction between TPACK and the three other knowledge types in the TPACK framework proposed by Mishra and Koehler (2006) (PCK, TCK, and TPK). Cox and Graham et al. (2009) also found it difficult to pinpoint PCK, TCK, and TPK in practice. Teachers usually work with concrete instructional objectives for the topics they are teaching. Decisions for technology use, content representation, and pedagogical approach tend to be considered concurrently. Furthermore, Archambault and Barnett (2010) expressed that one of the weaknesses of the TPACK framework is that it is limited in its ability to assist researchers in predicting outcomes or revealing new knowledge. While it focuses on three major areas—teaching, content, and technology—it does not represent the causative interaction or the direction of the relationship between and among these domains. These

findings may, hence, provide theoretical guidance for how teacher preparation programs might approach training candidates who can use technology in content-specific ways and how to measure science teachers' TPACK.

After studying the TPACK-based course, the findings show that a basic understanding of TK was observed among the participants more than an integrated knowledge of TPACK. The participants demonstrated knowledge of a combination of technology, pedagogy, and content, instead of an integration of all three. This could be because the activities in the course drew upon the integrative perspective, which defines TPACK as the combination or mixture of different types of knowledge. These findings provide initial guidelines for revising the course to shift to a transformative view that defines TPACK as a distinct set of knowledge constructed from other forms of teacher knowledge rather than a simple combination of parts (Angeli & Valanides, 2009; Gess-Newsome, 2002). The findings are consistent with previous research that provided empirical evidence showing that the transformative model did have some impact on student teachers' TPACK in particular topics of subject matter (Jang & Chen, 2010).

Moreover, it is clear that the majority of participants used technology as a tool for word processing or information retrieval instead of incorporating technology to support inquiry that promotes students' deeper conceptual understanding of scientific ideas. Accordingly, the study suggests that teachers should develop the TPACK necessary for the successful integration of educational technology and that the integration of educational technology when teaching science is especially important because of the subject's emphasis on scientific inquiry (Kim, Hannafin, & Bryan, 2007). These findings suggest that future TPACK-based courses for developing science student teachers' TPACK should focus on fostering continual engagement in scientific inquiry-based instruction. The course should provide opportunities for student teachers to use technology to incorporate more inquiry experiences. Therefore, not only will the future TPACK-based course provide, in transformative view, a way to develop science student teachers' TPACK but it will also include an inquiry-based instruction as suggested by the national curriculum for promoting the utilization of instructional technology in teaching.

The findings further indicated that student teachers' lack of direct teaching experiences limited them in effectively using or integrating technology into teaching (Chai et al., 2010). The TPACK-based course is a practical orientation used to delineate the TPACK that student teachers need to develop and then document consistently pursued goals. Hsu, Yeh, and Wu (2015) developed TPACK-Practical as a framework of unique knowledge that evolved from science teachers' TPACK and that was enriched with their practical experiences. The results recommended that teacher education programs should not only be conceptually integrated but also require authentic experiences and be continually constructed.

Conflicts of interest

None.

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