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Exploring the Factor Structure of the Constructs of Technological, Pedagogical, Content Knowledge (TPACK)

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In recent years, several survey instruments have been designed to measure the technological pedagogical content knowledge (TPACK) of teachers. Even though the TPACK framework was conceptualized as having seven constructs, researchers have only successfully validated the constructs of technological knowledge (TK) and content knowledge (CK). Constructs such as pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and TPACK have been found to be difficult to differentiate via factor analysis. This study explored how the contextualization of items in a TPACK to the constructivist-oriented use of ICT for self-directed and collaborative learning improved its construct validity. This survey was administered on 214 Singaporean pre-service teachers. Such an approach for designing this TPACK survey led to the successful identification of the seven theorized constructs through factor analysis. The implications on these findings on the design of TPACK surveys are discussed.

Keywords: Pre-service teachers, ICT, technological pedagogical content knowledge (TPACK)

Promoting student-centered learning with the constructivist-oriented use of information and communication technology (ICT) has been an underlying rhetoric for a myriad of educational reform movements in many countries. Many educators believe that such reform movements develop the intellectual, technical and social dispositions needed for the 21st century among its citizens (Fox & Henri, 2005; Partnership for 21st Century Skills, 2009; Voogt, 2010). It is obvious that for these reforms to be successful, teachers need to possess the necessary knowledge and skills to integrate ICT in classroom learning with a focus towards facilitating students' knowledge construction. However, empirical studies to date have not been able to document such transformative use of educational technologies in classrooms (e.g. Chai, Hong & Teo, 2009; Gao, Choy, Wong & Wu, 2009; Harris, Mishra, & Koehler, 2009). In order to facilitate teacher development for better integration of ICT, teacher educators propose that teacher education should move away from technocentric approach to emphasize pedagogy and content (Harris et al., 2009). The technological pedagogical content knowledge (TPCK or TPACK) framework (Mishra & Koehler, 2006) reflects such a shift and it has been employed in many recent studies. For example, Polly, Mims, Shepherd and Inan (2010) have used this framework to evaluate the US-based "Preparing Tomorrow Teachers to Teach with Technology" (PT3) initiative. The TPCK acronym was considered difficult to pronounce and many researchers criticized its unfriendly consonant. At the 9th Annual National Technology Leadership Summit, TPACK was proposed as a substitute of TPCK. The new acronym TPACK is easy to use and is better representing the quality of the model (i.e. technology, pedagogy, and content should be integrated as a "Total PACKage").

ELEMENTS OF TPACK

Published articles based on the notion of TPACK appeared around 2005 (see Angeli & Valanides, 2005; Koehler & Mishra, 2005; Niess, 2005). These researchers built on the work of Shulman (1986) in the area of pedagogical content knowledge (PCK), or the specialized forms of knowledge that teachers possess about the content knowledge (CK) in relation to teaching it to a specific groups of students. TPACK researchers advocate that PCK needs to be expanded to include technological knowledge (TK) because of the pervasiveness of technology in most developed countries. Niess (2008) defines TPACK as the "body of knowledge that teachers now need for teaching with and about technology in their assigned subject areas and grade levels" (p. 224). TPACK is therefore derived from its constituents that include technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK).

Obviously, TK refers to mainly the technical skills involve in operating technology tools such as computers and software programs. Pedagogical knowledge can refer to a wide range of knowledge that are related to teaching including classroom management issues, pedagogical approaches such as problem-based learning and knowledge about students' psychology. Subject matter knowledge about a particular field of study is referred to as CK (Koehler & Mishra, 2008). These three forms of knowledge are synthesized by different educators and subject matter experts to form technological content knowledge (TCK), technological pedagogical knowledge (TPK), and PCK. TCK includes knowledge about how content can be represented by and researched with technology without the consideration of implemented pedagogy or teaching (Cox & Graham, 2009). Koehler and Mishra (2008) cited the use of X-ray in medical practice as an example of TCK while Cox and Graham (2009) provided the example of a geologist using ice-penetrating radar to map out the structure of glacier. TPK refers to knowledge about how technology can enhance students learning without considering the subject matter. For example, there are guidelines in using asynchronous online discussion regardless of what topic students will be discussing. When teachers synthesize all three forms of knowledge, that is, TK, PK, and CK for a particular group of students for a particular subject matter, the TPACK is formed and enacted. Figure 1 illustrates the basic relations between these seven constructs. Table 1 shows the definition and example for each TPACK construct.

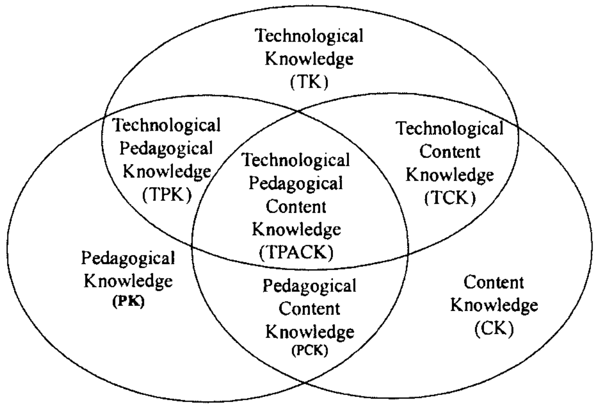

Figure 1. *TPACK framework, as depicted by Mishra and Koehler (2006, p. 1025).*

The articulation of TPACK as a theoretical framework for understanding the types of knowledge teachers need for ICT integration in classroom teaching and learning advances the field of educational technology (AACTE, 2008). However, researchers have commented that the boundaries of the TPACK constructs can be at times be rather vague, making it difficult to categorize instances of ICT integration (Cox & Graham, 2009; Koehler & Mishra, 2008; Lee & Tsai, 2010). This prompted Cox and Graham (2009) to perform conceptual analyses of the various constructs of the TPACK framework. Their work helps to bring in more clarity about the constructs by providing examples of mutually exclusive instances of description for all seven constructs. Researchers have also attempted to formulate TPACK surveys with construct validity for the seven constructs (see Archambault & Barnett, 2010; Koh, Chai, & Tsai, 2010). However, this has so far remained a challenge.

The Validation of TPACK Surveys

To date, a number of TPACK surveys have been created. In the USA, Koehler and Mishra (2005) constructed a survey to assess graduate students' and faculties' learning and perceptions. The survey is course specific and data were only collected through

Table 1
The Constructs of TPACK

TPACK Knowledge Constructs	Definition	Example
TK (Technological Knowledge)	Knowledge about features, capacities, and applications of technologies	Knowledge about how to use Web 2.0 tools (e.g. Wiki, Blogs, Facebook)
PK (Pedagogical Knowledge)	Knowledge about the students' learning, instructional methods and process, different educational theories, and learning assessment to teach a subject matter	Knowledge about how to use problem-based learning (PBL) in teaching different scientific topics (e.g. lights, electrics)
CK (Content Knowledge)	Knowledge of the subject matter	Knowledge about Science or Math subjects
TPK (Technological Pedagogical Knowledge)	Knowledge of the existence and specifications of various technologies to enable teaching approaches	Knowledge about how to use Wiki as an online tool to enhance collaborative learning
TCK (Technological Content Knowledge)	Knowledge about how to use technology to represent the content in different ways	Knowledge about how to use animations to show the operations of solar system
PCK (Pedagogical Content Knowledge)	Knowledge of adopting pedagogical strategies to make the subject matter more understandable for the learners	Knowledge about how to use analogical skills to teach math concepts
TPACK (Technological Pedagogical Content Knowledge)	Knowledge of using various technologies to teach and represent the designated subject content	Knowledge about how to use Wiki as a communication tool to enhance collaborative learning in social science

a small sample (N<20). Schmidt et al. (2009) created the first general TPACK survey entitled "Survey of Pre-service Teachers' Knowledge of Teaching and Technology". The 58-item survey assessed all seven constructs of the TPACK of primary school teachers with respect to the content areas of Mathematics, Social Studies, Science, and Literacy. Initial items crafted were subjected to experts review. The pilot-test involving 124 American pre-service teachers yielded Cronbach alphas ranging from 0.75 to 0.92. Factor analyses were performed on each construct, perhaps due to the relatively small sample. Concurrently, a number of other TPACK surveys designed for more specific context have been constructed and implemented. For example, Archambault and Barnett (2010) surveyed 596 K-12 American teachers involved in online teaching with a 24-item survey. The results indicated that only three factors were obtained. While CK, PK and PCK items loaded as one factor, the TPK, TCK, and TPCK items loaded as another. The last factor comprised of TK items. Another TPACK survey specifically designed in the teaching of science was designed by Graham et al. (2009). This 30-item survey was tested with 15 in-service teachers. However, these items cover only four constructs (i.e. TK, TCK, TPK, and TPACK). The validity of this set of items still needs to be tested with larger samples.

In Asia, Lee and Tsai (2010) tested a 30-item survey on Taiwanese teachers' self-efficacy of web-based TPACK (N=558). Their original proposed model comprises six constructs namely web-general, web-pedagogical knowledge, web-content knowledge, web-pedagogical-content knowledge, web-communicative, and attitudes towards web-based instruction. The first four constructs correspond to the constructs of TK, TPK, TCK and TPACK. Their factor analyses yielded five factors, with web-pedagogical knowledge and web-pedagogical-content knowledge loading as one factor.

In Singapore, Koh et. al (2010) made minor adaptations of Schmidt et al.'s (2009) survey to contextualize the subject areas surveyed, and tested its factor structure using a large sample of Singaporean pre-service teachers (N=1185). The exploratory factor analysis (EFA) yielded four factors which they labeled as TK, CK, Knowledge of Teaching with Technology (KTT), Knowledge of Pedagogy (KP), and Knowledge from Critical Reflection (KCR). Items originally categorized as TCK, TPK and TPACK loaded as one to form the KTT. This pattern of loading seems to be similar to the studies conducted by Archambault and Barnett (2010) and Lee and Tsai (2010). All three studies indicate that items belonging to overlapping constructs related to technology, that is, TCK, TPK, and TPACK may group together while there is a tendency for PK, CK and PCK to form one factor. In Koh et al. (2010), two TPK items formed KCR. Both items contain phrases like thinking deeply or critically about the use of technology, hence the new label. Given the problems related to the factor analyses, Chai, Koh and Tsai (2010) attempted to survey pre-service teachers' self-reported development by using a TPACK survey that excluded the TCK, PCK, and the TPK items. They were able to obtain the four factors (TK, PK, CK, and TPACK) with good factor loadings (>.50). However, when the second order constructs of TCK, PCK, and TPK are removed, it limits the understanding of how these intervening forms of knowledge may contribute to the ultimate formation of TPACK.

In summary, research to date has not been able to validate a TPACK survey with respect to the seven constructs postulated by Mishra and Koehler (2006). The main difficulty lies in crafting items that effectively distinguish the seven constructs. This study attempts to build on previous research to create a survey that could bridge this gap.

METHOD

Participants and Context

Three hundred and thirty-six Singaporean pre-service teachers who were attending a 12-week compulsory course on the integration of ICT for teaching and learning were invited to participate in this study by filling up an online survey. The survey was administered during the first half of the semester, after the pre-service teachers were introduced to the concept of meaningful learning with ICT (Jonassen, Howland, Marra, & Crismond, 2008). The response rate was 63.7% and (n = 214) participation was voluntary. The mean age of the pre-service teachers is 25.6 years (SD =4.99). The wide range of age differences is because some pre-service teachers have worked in other professions before joining teaching. Among the respondents, there are 65 male teachers who comprised 30.4% of the respondents, which is quite typical for the teaching profession in Singapore.

The distribution of primary and secondary level pre-service teachers is 39.7 % (n = 85) and 60.3% (n = 129), respectively. The primary teachers are regarded as generalists and are trained to teach English, Mathematics, and Science/Social Studies (three subjects) or mother tongue languages and Moral Education. Therefore, content knowledge required for teaching these subjects are taught during their pre-service training. The secondary teachers are trained to teach two content subjects that are closely related to their undergraduate specialization. While at times there are secondary pre-service teachers who specialize in English and Chemistry, the more usual combination of teaching subjects would be English and a humanity subject or a science subject with mathematics. The secondary pre-service teachers are regarded as specialists. To avoid creating very long survey that may be confusing to the participants, we only surveyed the pre-service teachers' self rating of their first and second teaching subjects in this study.

The ICT course is based on the framework of meaningful learning (Jonassen et al., 2008), which is oriented towards the constructivist use of ICT to support student-centered learning. This framework was chosen because it supports the vision of Singapore's ICT Masterplan 3 (mp3), which emphasizes the development of Singapore students' ability to harness ICT to support self-directed learning and collaborative learning (Teo & Ting, 2010). Pre-service teachers need to be cognizant of similar pedagogies. Therefore, the course uses constructivist pedagogies that involve pre-service teachers in solving authentic problems through active and constructive learning supported by ICT. Within the framework, pre-service teachers are encouraged to learn in collaborative social settings and assume the role of intentional learners.

The Instrument

The instrument used in this study was adapted from Schmidt et al. (2010), Koh et al. (2010) and Chai et al. (2010). All the seven constructs of the TPACK are represented. The initial instrument consists of 36 items. With the exception of two TPK items that were eliminated due to low factor loadings, all the items are provided in Table 2. As Singaporean pre-service teachers are trained to teach at least two subjects, items involving subject matter labels such as Social Studies, Mathematics in Schmidt et al.'s survey have been replaced by "first teaching subject" and "second teaching subject". However, data about the pre-service teachers' exact teaching subjects were still collected as part of their demographic data. Informed by Cox and Graham's (2009) conceptual

Table 2.
Results of Exploratory Factor Analysis for TPACK survey (n = 214)

		Factors							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
TPACK4	I can use strategies that combine content, technologies and teaching approaches that I learned about in my coursework in my classroom.	.83							
TPACK3	I can select technologies to use in my classroom that enhance what I teach, how I teach and what students learn.	.82							
TPACK5	I can provide leadership in helping others to coordinate the use of content, technologies and teaching approaches at my school and/or district.	.72							
TPACK2	I can teach lessons that appropriately combine my CS2, technologies and teaching approaches.	.69							
TPACK1	I can teach lessons that appropriately combine my CS1, technologies and teaching approaches.	.66							
TK5	I am able to use social media (e.g. Blog, Wiki, Facebook).		.81						
TK6	I am able to use conferencing tools (Yahoo, IM, MSN Messenger, ICQ, Skype etc).		.80						
TK2	I can learn technology easily.		.73						
TK3	I know how to solve my own technical problems when using technology.		.65						
TK1	I have the technical skills to use computers effectively.		.62						
TK4	I am able to create web pages.		.54						
CKCS2-1	I have sufficient knowledge about my second teaching subject (CS 2).			.84					
CKCS2-2	I can think about the content of my second teaching subject (CS2) like a subject matter expert.			.82					
CKCS2-3	I am able to develop deeper understanding about the content of my second teaching subject (CS 2).			.62					
PCK4	Without using technology, I can help my students to understand the content knowledge of second teaching subject (CS2) through various ways.				.88				
PCK3	Without using technology, I know how to select effective teaching approaches to guide student thinking and learning in my second teaching subject (CS2).				.84				
PCK2	Without using technology, I can help my students to understand the content knowledge of my first teaching subject (CS1) through various ways.				.76				
PCK1	Without using technology, I know how to select effective teaching approaches to guide student thinking and learning in my first teaching subject (CS1).				.59				
PK4	I am able to help my students to reflect on their learning strategies.					.87			
PK3	I am able to help my students to monitor their own learning.					.82			
PK6	I am able to guide my students to discuss effectively during group work.					.82			
PK2	I am able to guide my students to adopt appropriate learning strategies.					.72			
PK5	I am able to plan group activities for my students.					.71			
PK1	I am able to stretch my students' thinking by creating challenging tasks for them.					.62			

Continuation of Table 2.....

		Factors							
		1	2	3	4	5	6	7	8
CKCS1-1	I have sufficient knowledge about my first teaching subject (CS1).						.80		
CKCS1-2	I can think about the content of my first teaching subject (CS1) like a subject matter expert.						.72		
CKCS1-3	I am able to develop deeper understanding about the content of my first teaching subject (CS1).						.47		
TCK1	I know about the technologies that I have to use for the research of content of first teaching subject (CS1).							.68	
TCK3	I know about the technologies that I have to use for the research of content of my second teaching subject (CS2).							.68	
TCK2	I can use appropriate technologies (e.g. multimedia resources, simulation) to represent the content of my first teaching subject (CS1).							.58	
TCK4	I can use appropriate technologies (e.g. multimedia resources, simulation) to represent the content of my second teaching subject (CS2).							.51	
TPK3	I am able to facilitate my students to use technology to plan and monitor their own learning.								.54
TPK4	I am able to facilitate my students to use technology to construct different forms of knowledge representation.								.54
TPK5	I am able to facilitate my students to collaborate with each other using technology.								.45

Extraction Method: Principal Axis Factoring.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 19 iterations.

analyses, the items for TCK include technology for the research and representation for the subject matter (see TCK1, and TCK3). Given the course context, the items constructed for PK were redesigned to focus on self-directed learning (e.g., PK3 and PK4) and collaborative learning (e.g., PK5 and PK6). The items for TPK are focused on constructivist teaching practice supported by technology (e.g., TPK4 and TPK5). Items for TK assess pre-service teachers' perceived technological competencies for general computer technology (e.g., TK3 and TK4). As per the context of study, we have also included items for technologies supporting constructivist teaching such as the Web 2.0 technologies and social media (e.g., TK5).

Data Analysis

The data analyses involve both exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). For the EFA, we employed the procedures recommended by Costello and Osborne (2005) where factors with eigenvalues more than one and factor loading greater than .40 are selected. After removing items with low factor loadings and cross loadings, CFA was performed using AMOS 18, following the procedures recommended by Hair, Black, Babin, and Anderson (2010).

FINDINGS

EFA and CFA

The EFA extracted 8 factors with eigenvalues greater than one, explaining 78.5% of the cumulative variances. The eight factors included the seven original TPACK constructs but the CK construct was partitioned into two factors respectively for the first teaching subject (i.e., CKCS1) and the second teaching subject (i.e., CKCS2). The pattern matrix is depicted in Table 2.

The survey created was found to be valid and reliable for the sample of pre-service teachers

Table 3
Pearson Correlations Among the TPACK factors

	CKCS1	CKCS2	PK	TK	PCK	TCK	TPACK	TPK
CKCS1	1							
CKCS2	.53**	1						
PK	.54**	.41**	1					
TK	.18**	.23**	.28**	1				
PCK	.38**	.24**	.39**	.12	1			
TCK	.44**	.37**	.54**	.45**	.31**	1		
TPACK	.41**	.35**	.55**	.45**	.31**	.77**	1	
TPK	.26**	.19**	.57**	.53**	.32**	.60**	.68**	1

**. Correlation is significant at the 0.01 level (2-tailed).

surveyed. The overall reliability coefficient (Cronbach alpha) for the 8 factors model is 0.95. The respective reliability coefficients are TK (0.87), CKCS1(0.84), CKCS2(0.86), PK(0.93), PCK(0.87), TPK(0.90), TCK(0.92), TPACK(0.94). As shown in Table 2, the pre-service teachers perceived their first teaching subject and second teaching subject as two distinctive factors. In addition, the Pearson's correlations of all the factors were positive and significant ($p<0.01$), except for TK and PCK (see Table 3 below). The insignificant correlation between TK and PCK may be because the phrase "without using technology" was used at the beginning of all PCK items, which led the respondents to perceive little or no relationships between the constructs.

CFA was performed with AMOS 18 to further test the model. The eight factors model yielded satisfactory model-fit for the pre-course survey (χ^2 = 950.98, χ^2/df = 2.09, $p<.001$, TLI = .909, CFI = .922, RMSEA = .071). These indices are regarded as acceptable by Hair et al. (2010).

DISCUSSION

Building on the work of Lee and Tsai (2010), Chai et al., (2010) and Koh et al. (2010), this study contributes to the extant study of TPACK through the creation of a survey with construct validity for all the seven TPACK constructs postulated by Mishra and Koehler (2006). Pre-service teachers were able to distinguish the overlapping construct such as the TCK, PCK and TPK which were reported to be problematic in prior studies such as Lee and Tsai (2010), Chai et al., (2010) and Koh et al. (2010).

The construct validity was derived primarily through further contextualization of the TPACK framework to the ICT course offered for the Singaporean pre-service teachers. We adapted the TPK items according to Jonassen et al.'s (2008) meaningful learning framework which emphasizes the use of active and constructive learning to solve authentic problems in group settings. We crafted items for PK that were directed at the pedagogical foci of self-directed learning and collaboratively learning with respect to Singapore's third IT Masterplan for Education. Also, we have facilitated the survey respondents to distinguish the PCK items from TCK and TPK items by inserting the phrase "without using technology". The findings seem to suggest that when the TPACK framework is employed to survey pre-service or in-service teachers' perceived knowledge levels, consideration needs to be given to the specific type of pedagogical approaches they intend to employ. Schimdt et al.'s (2009) survey seems to be targeting at general pedagogies and TPK item such as "I can choose technologies that enhance the teaching approaches for a lesson" (p. 147) may not adequately distinguish between using technology use for teacher-centered and student-centered instruction. From the perspective of content validity, surveys constructed to assess pre-service teachers' TPACK should measure more precisely the type of pedagogy that the integration of ICT is intended to achieve. In addition, we believe that subject-based TPACK may also help respondents better distinguish between the different TPACK categories. This can be done by designing subject-specific items for TCK and PCK and further contextualizing these in terms of the technologies to be employed in a course (e.g., Web 2.0; data logging devices). Lee and Tsai's (2010) study is one such example.

The breaking up of CK into two constructs according to the first and second teaching subject of the teachers could present problems to the constructs of TCK and PCK. Given the two constructs of CK, the PCK and TCK items should also be separated accordingly. This was not so in this study perhaps because of the small number of items (four each) for TCK and PCK. Future research may need to explore if adding more items for each of the respondents' teaching subjects could help them better distinguish the corresponding TCK and PCK items.

The limitation of this study lies in its sample size. The current items-to-participants ratio is 1: 5.9. It would be ideal to raise it to a ratio of 1:10 (Hair et al., 2010). The small sample also makes it inadequate for further analyses such as employing the structural equation modelling to find out how each construct contribute to the other constructs. We would suggest that future research with larger samples of pre-service teachers to facilitate such kinds of analyses. Besides this, teacher educators could also structure assignments employing the TPACK framework and then correlate their assignment grades with pre-service teachers' self rating on the TPACK survey. This can provide further evidence to confirm or deny the usefulness of the TPACK survey.

CONCLUSION

This study has presented an example of how the construct validity of TPACK surveys can be improved with respect to the theoretical postulations of Mishra and Koehler (2006). Future research is needed to further explore the strategies for improving the validity of TPACK surveys, which is an important instrument that can be used to support ICT course evaluation in teacher education programmes.

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