教育資料與圖書館學

Journal of Educational Media & Library Sciences

http://joemls.tku.edu.tw

Vol. 52 , no. 1 (Winter 2015) : 59-82

國中數學教師科技學科教學知識之探究

Exploring Mathematics Teachers' Perception of Technological Pedagogical Content Knowledge

賴 婷 鈴* Ting-Ling Lai*
Assistant Professor
E-mail：tlai@mail.tku.edu.tw

林 曉 芳 Hsiao-Fang Lin
Assistant Professor

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Journal of Educational Media & Library Sciences 52: 1 (Winter 2015) : 59-82
DOI:10.6120/JoEMLS.2015.521/0642.RS.CE

Research Article

Exploring Mathematics Teachers' Perception of Technological Pedagogical Content Knowledge

Ting-Ling Lai[a*] Hsiao-Fang Lin[b]

Abstract

The purpose of the study is to develop an instrument for junior high school mathematics teachers to evaluate their technological pedagogical content knowledge. The survey tool is based on Koehler and Mishra's TPACK framework and strengthened mathematics content knowledge and pedagogical content knowledge in the framework. 526 junior high school mathematics teachers in Taiwan were recruited to validate the survey. Confirmatory factor analysis was applied to examine the validity. The results showed that survey tool reached good validly and reliability. We also explored gender, age, and seniority and other demographic factors to reflect current junior high school mathematics teachers' TPACK in Taiwan.

Keywords: *TPACK, In-service teacher, Confirmatory factor analysis*

Introduction

For decades, teaching has been considered a complex cognitive skill that requires various types of knowledge bases. Teacher educators have been exploring what teachers need to know as well as how to teach well. The basic traditional requirement for becoming a teacher is to possess plentiful content knowledge (CK) in a specialized subject matter; however, research-oriented CK has been found to be challenging for students to learn effectively. Teachers need to know how to transform the subject matter knowledge for students to understand. Shulman (1986) proposed pedagogical content knowledge (PCK) to bridge CK and teaching practice. PCK is defined as a type of knowledge that teachers develop to represent and formulate their subject matter and make it comprehensible for students (Shulman, 1986). PCK is a unique form of knowledge that distinguishes teachers from content specialists; it includes the knowledge of how subject matter can be represented, what (mis) conceptions of

[a] Assistant Professor, Department of Educational Technology, Tamkang University, Taipei, Taiwan.
[b] Assistant Professor, Graduate Institute of Curriculum and Instruction, MingDao University, ChangHua, Taiwan
* Principal author for all correspondence. E-mail: tlai@mail.tku.edu.tw

2014/07/24 received; 2015/01/06 revised; 2015/01/13 accepted

the topics can be found for learners, and how to adapt a topic for learners with diverse interests and abilities (Magnusson, Krajcik, & Borko, 1999; Shulman, 1986).

With the recent extensive use of digital technology in daily life, technology is considered an essential component for teaching support and learning in classrooms. In mathematics education, technology facilitates learners to visualize abstract ideas as well as organize and analyze data, so that learners can focus on decision-making, reflection, reasoning, and problem-solving (National Council of Teachers of Mathematics, 2000). However, studies found that teachers still lack the knowledge and skills to integrate technology in the classroom (e.g., Lee, Suharwoto, Niess, & Sadri, 2006). Researchers indicated that simply adding technological components into teaching and content domain is insufficient for technology integration; teachers need to possess technological pedagogical knowledge (TPK) to development knowledge for technology integration (Angeli & Valanides, 2009; Graham, 2011). Models and frameworks have been proposed in different disciplines, for example, information and communication (ICT)-related PCK (Angeli & Valanides, 2009) and technological content knowledge (TCK; Niess, 2005). Mishra and Koehler (2006) indicated that good teaching with technology requires understanding the combination of content, pedagogy, and technology to develop appropriate instructional strategies and representations. Mishra and Koehler (2006) adapted Shulman's PCK model and proposed a conceptual framework of Technological Pedagogical Content Knowledge (TPACK, formerly TPCK). The TPACK framework contains seven sets of knowledge [i.e., CK, PK, technological knowledge (TK), TPK, TCK, PCK, and TPACK]. This framework provides recommendations for instructional design for teacher educators in technology integration from various approaches (Graham, 2011).

A number of studies have adopted Koehler and Mishra's model to investigate teachers' TPACK, having focused mostly on pre-service teachers' development of the TPACK in teacher education programs (e.g., Chai, Koh, & Tsai, 2010; Chai, Koh, Tsai, & Tan, 2011). Other studies have explored the effects of teachers' use of specific technology and their TPACK development (e.g., Archambault & Barnett, 2010; Jang & Tsai, 2012; Lee & Tsai, 2010). However, these surveys are generic; they intended to assess teachers' TPACK for various subject areas (e.g., literature, science, and the social sciences). Although teaching various subjects requires diverse pedagogical knowledge (PK) and PCK (Koehler & Mishra, 2006; Shulman, 1986), it also necessitates different TPK, TCK, and TPACK when integrating technology into the classroom. These generic survey items may not reflect adequate professional knowledge bases. Furthermore, most TPACK studies have explored pre-service teachers' TPACK, and researchers have found that PCK might differ between pre-service and in-service teachers (e.g., Tirosh, 2000). These study results may not have fully revealed in-service teachers' TPACK. Therefore, an investigation of in-service teachers' TPACK in a single subject may provide information on how to improve teacher professional development. The purpose of our study is twofold: (a) to develop a TPACK assessment tool for junior high school mathematics teachers; and (b) to investigate junior high school mathematics teachers' TPACK in Taiwan.

Literature Review

TPACK Framework

The traditional viewpoint of teaching decisions is made through the content; however, with the rise of technology integration in teaching and learning, the use of technology may enable or constrain teachers' use of representations or explanations regarding their subject matter (Mishra & Koehler, 2006). Within the TPACK framework, the three primary categories of knowledge, CK, PK, and TK, form a Venn diagram, which results in four more components: TPK, TCK, PCK, and TPACK. The seven categories of knowledge are defined as follows:

(a) CK is the knowledge regarding subject matter that is to be learned and taught. Specifically, it contains the concepts, principles, rules, and evidence of a subject area.

(b) PK is knowledge regarding methods, strategies, or practices that teachers have learned to teach and evaluate student learning. Here we include instructional strategies, activities, classroom management, lesson plans, and student evaluation.

(c) TK is knowledge regarding the use of digital technology. This includes the ability to operate technology, and to use software to adapt existing instructional material, or to create new ones.

(d) PCK refers to the knowledge of teaching and learning principles as well as strategies that are used to deliver content effectively. This knowledge type considers what makes concepts difficult to learn, what conceptual representations are appropriate to explain difficulties and misconceptions for learners, and what prior knowledge learners possess.

(e) TPK is knowledge regarding how different information communication technology (ICT) can be used in teaching and facilitating student learning. This includes knowledge on which ICT improves teaching effectively, and the ability to learn and adapt new ICT for teaching.

(f) TCK concerns knowledge regarding how to incorporate technology that creates better representations of specific content.

(g) TPACK is the integrative knowledge of the interaction of content, pedagogy, and technology, and includes teachers' understanding as well as the use of technology-enhanced, content-specific pedagogical strategies for teaching subject matter and representation. Figure 1 shows the TPACK framework.

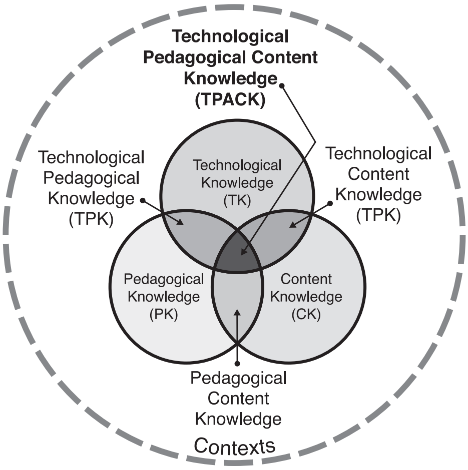

Figure 1 TPACK Framework

Source: TPACK.org, 2012, reproduced by permission.

The Mishra and Koehler (2006) TPACK model has raised scholarly debate on how to develop teachers' knowledge bases for technology integration; yet, certain challenges and criticisms have also emerged. Angeli and Valanides (2009) argued that each component in TPACK is fuzzily defined, and researchers have a different understanding of PCK, TCK, TPK, and TPCK. In addition, the nature of TPACK is disputable regarding whether TPCK is a distinct form of knowledge or whether the changes in TPCK lead to alterations in other components within the framework (Cox & Graham, 2009; Niess, 2011). Furthermore, the relationship among the seven components is unclear (Angeli & Valanides, 2009; Archambault & Barnett, 2010; Graham, 2011), and the integrative or transformative viewpoint of the model may affect how researchers assess TPACK. Recent literature review pointed that TPACK as a distinct body of knowledge, and researchers suggested that contextualize TPACK on a specific domain may improve our understanding of TPACK (Graham, 2011; Voogt et al., 2012).

PCK and TPCK in mathematics education

Ball, Thames, and Phelps (2008) observed mathematics teachers' practice, and found that mathematics teachers need to explain the concepts, principles, and procedures, but also interpret student errors and evaluate alternative algorithms. Mathematics teachers need advanced mathematical knowledge and skill to decide whether a method or procedure works in general. These practices necessitate mathematics knowledge, which encompasses more than Shulman's definitions of CK and PCK. Therefore, they proposed a framework of Mathematics Knowledge for Teaching (MKT) that integrated CK and PCK, and divided it into six categories. The CK domain includes common content knowledge (CCK), specialized content knowledge (SCK), and horizon content knowledge (HCK). CCK is the knowledge that one can correctly solve mathematics problems; it can be used under numerous circumstances other than in teaching. SCK refers to mathematical knowledge and skills that are specific to teaching mathematics, and HCK is defined as knowing how a specific concept is related to other concepts in mathematics curricula. Parallel to Shulman's PCK are an additional three knowledge categories: knowledge of content and students (KCS), knowledge of content and teaching (KCT) and knowledge of content and curriculum (KCC). KCS refers to the knowledge of common student conceptions and misconceptions regarding specific mathematical content, KCT is knowledge regarding what examples to use or the advantages and disadvantages of representations used to teach specific content, and KCC is knowledge regarding instructional materials and programs (Ball et al., 2008). Despite factor analysis having not empirically supported the existence of the distinct components of the MKT model (Baumert et al., 2010), this model is considered most influential, and best describes CK and PCK in mathematics education (Depaepe, Verschaffel, & Kelchtermans, 2013).

For mathematics education, Niess et al. (2009) proposed a model for preservice mathematics teachers' TPACK development. The model included standard indicators in four areas (i.e., the design and development of technology-rich learning environments, the application of methods and strategies for applying appropriate technology to maximize student learning, the application of technology to facilitate assessment, and the use of technology to enhance teachers' productivity and proactivity). This model seems generic, and does not address mathematics teaching specifically (Voogt, Fisser, Roblin, Tondeur, & van Baak, 2012). Therefore, to better assess mathematics teachers' TPACK, we developed a survey based on Mishra and Koehler's TPACK model, and expanded CK and PCK to include CCK, SCK, and KCC from MKT.

Assessment of TPACK

To investigate teachers' perceptions of TPACK, researchers have developed surveys on the basis of the Mishra and Koehler (2006) model. Some studies have explored pre-service teachers' TPACK in a generic survey (e.g., Chai et al., 2010; Schmidt et al., 2009), some have focused on in-service teachers in science education (e.g., Lee & Tsai, 2010; Lin, Tsai, Chai, & Lee, 2013), and still others have examined specific pedagogical uses of technology knowledge (e.g., Jang & Tsai, 2012). Most of these studies have used exploratory factor analysis (EFA) to examine the validity of the surveys; few studies can verify Mishra and Koehler's

(2006) seven components of the TPACK model. Schmidt et al. (2009) developed a TPACK survey tool, Survey of preservice teacher's knowledge of teaching and technology, and examined how pre-service teachers develop and apply TPACK through their teacher preparation program. Through factor analysis within each subscale, they selected 24 items, and validated the tool. The participants in that study were 124 k-6 pre-service teachers who taught all of the subjects in their classroom. The question items used to assess CK focused on the whether teachers had an in-depth and broad knowledge of the subjects, and if they knew various examples in a diverse range of subjects (i.e., math, science, social studies, and literature). Koh, Chai, and Tsai (2010) recruited 1,185 pre-service teachers to validate a TPACK survey tool. Through EFA, they found that participants were unable to distinguish between TCK and TPK. The items from TPK, TCK, and TPACK were loaded as one factor, and items from PK and PCK were loaded as another factor. The researchers renamed the five identified factors as TK, CK, knowledge of pedagogy (KP), knowledge of teaching technology (KTT), and knowledge from critical reflection (KCR).

Few studies have explored in-service teachers' TPACK. Graham et al. (2009) designed a survey to measure in-service science teachers' confidence in TPACK. This survey included 31 items to measure four components (i.e., TK, TPK, TCK, and TPACK) through 15 participant responses, and their results indicated that these in-service science teachers' confidence in TK is foundational to developing confidence in the other three forms of knowledge measured. Lin et al. (2013) investigated 222 primary and secondary school pre-service and in-service science teachers' perceptions of TPACK in Singapore. The structural equation model (SEM) analysis results confirmed the Mishra and Koehler (2006) seven-factor model. That study found that in-service teachers had significantly higher confidence compared with pre-service teachers for CK and PK.

Some survey tools have been developed to assess teachers' perceptions when they incorporate specific technology tools or instructional methods. Archambault and Barnett (2010) surveyed 1,795 k-12 online teachers' TPACK. Through factor analysis, they found three factors: PCK, TK, and TCK. CK, PK, and PCK were loaded as one factor and labeled PCK, and the items of TPK, TCK, and TPCK were loaded as TCK, with TK being the only clear factor. Lee and Tsai (2010) developed a Technological Pedagogical Content Knowledge-Web (TPCK-W) Survey to assess teachers' self-efficacy in web-based instruction. The participants were 558 teachers from select elementary schools to high schools in Taiwan. Through factor analysis, their survey identified five factors: web general, web communication, web CK, web PCK, and attitude. The results showed that web PK and web PCK were loaded as one factor. Chai et al., (2011) explored the PK of meaningful learning and web competence. They investigated 834 pre-service teachers teaching various content areas in Singapore. The survey items included 28 items from the Schmidt et al. (2009) survey, and added meaningful learning to replace generic PK. For TK, they included web-based technology; thus, TK was measured as web competence. The factor analysis results showed five factors in the pre-course survey; this meant that teachers were able to distinguish among TK, PK, CK, TPK, and TPACK. Jang and Tsai (2012) surveyed 614 in-service elementary mathematics and science teachers in the use of interactive whiteboards (IWBs) in Taiwan. In addition to the seven categories from the TPACK framework, the survey included context knowledge (CxK), which refers to students' prior knowledge, misconceptions, learning difficulties in each subject, and an evaluation of student understanding. The TPACK questionnaire underwent factor and item analyses. The results yielded four major components: CK, TK, PCKCx, and TPCKCx. Items from PK and PCK were combined as PCKCx, whereas items from TPK, TCK, and TPCK were loaded as TPCKCx. The results showed teachers who use IWBs had significantly higher CK, PCKCx, TK, and TPACKCx compared with those who do not use IWBs. From aforementioned these studies, we found that most of them have investigated pre-service teachers' TPACK, most of survey items were content-general. As researchers pointed that TPACK needs to be contextualized on a specific lesson topic (Graham et al., 2009), it also needs to examine in-service teachers' TPACK for one specific subject. Further, most studies merely used EFA to extract factors from the framework that might not be able to address the complex nature of TPACK model (Lee & Tsai, 2010), therefore, in present paper, we adopt MKT to develop TPACK instrument and use confirmative factor analysis to verify the Mishra and Koehler (2006) seven factors of TPACK model.

Teacher's TPACK by gender and teaching experience

Previous studies have shown that males and females have different knowledge and attitude toward ICT (Kay, 2006; Markauskaite, 2006). Few studies have investigated gender differences in teachers' TPACK. Koh et al. (2010) found that male pre-service teachers' TK was higher than that of their female counterparts. Lin et al. (2013) revealed that female in-service teachers had higher confidence in PK but less confidence in CK. Jang and Tsai (2012) found that gender differences did not have any significant effects on elementary school science and math teachers' IWB-based TPACK. Later, they conducted another study to investigate 1,292 secondary science teachers in Taiwan, and found that male teachers rated themselves higher than did female teachers in TK (Jang & Tsai, 2013).

Researchers also explored other demographic factors such as age, teaching experiences (seniority), technology integration experiences, and their relationship with TPACK. Lee and Tsai (2010) conducted the correlation analysis and found that older teachers with more teaching experience were less confidence about their web-TPACK. Lin et al. (2013) also used the correlation analysis to find that in-service teachers' TK, TPK, TCK and TPC(K) were significantly correlated with their age negatively. They concluded that female in-service science teachers tended to feel less confident in technology-related knowledge base (i.e., TK, TPK, TCK and TPACK) when the age increased. Koh, Chai, and Tsai (2014) surveyed 354 elementary, secondary school and junior college teachers in Singapore. From the correlation analysis results, they found that teaching experiences had significant influence on constructivist-oriented TPACK whereas age and gender did not.

In Jang and Tsai (2012) study, experienced elementary science and mathematics teachers had higher CK, pedagogical content knowledge in context (PCKCx), and TPACK than novice teachers. In the later study, they found experienced secondary science teachers had higher rating in CK and PCKCx, while science teachers with less teaching experience had higher rating in TK and technological content knowledge in context (TPCKCx) (Jang & Tsai, 2013). Both studies used ANOVA to find the significant differences among four groups of teaching experience, however, without post hoc tests, it is unclear which group was better than others. Teacher educators have noted that teachers' needs in professional development might vary depending on their career stages (Richter, Kunter, Klusmann, Lüdtke, & Jürgen, 2011), this warrants further investigating to examine the interaction effect of gender and other demographic characters factors on secondary school mathematics teachers' TPACK.

Method

Subjects

Our study participants were public junior high school mathematics teachers in Taiwan. We recruited 526 math teachers (approximately 56% of them were men) for the study. In total, 257 participants (48.9%) were between 31 and 40 years old, 205 teachers (39.0%) were older than 40 years, and 64 teachers (12.2%) were under 30 years of age. Regarding their teaching experience, 232 teachers (44.1%) taught for 11-20 years, 210 teachers (39.9%) taught less than 10 years, and 83 teachers (15.8%) taught for more than 21 years. Concerning technology integration experience, approximately 71% of participants had experience, whereas 29% of teachers had no technology integration experience. Demographic information is listed in Table 1.

Table 1 Demographics Data of the Subjects

N=526

Item	Group	Count	Percentage (%)
Gender	Male	294	55.9
	Female	230	43.7
	missing	2	.4
Age	Under 30 yr.	64	12.2
	31-40 yr.	257	48.9
	Above 41 yr.	205	39.0
Teaching experiences	0-10 yr.	210	39.9
	11-20 yr.	232	44.1
	21-more yr.	83	15.8
	Missing	1	.2
Technology Integration Experience	Yes	374	71.1
	No	152	28.9
Total		526	100.0

Source: This study.

Instrument development

To explore Taiwan junior high school mathematics teachers' perception of TPACK, we developed a survey for mathematics teachers (TPACK-MT). The constructs in the survey were based on the Mishra and Koehler (2006) framework containing seven subscales (i.e., CK, PK, TK, TCK, PCK, TPK, and TPACK) and existing survey tools (e.g., Chai et al., 2009; Lin et al., 2013; Schmidt et al., 2009). To better assess mathematics teachers' CK and PCK, we followed the recommendations by Ball et al. (2008), and created question items to assess math pedagogical content knowledge (PCK-M) and general pedagogical content knowledge (PCK-G). A sample question for PCK-M was, "I am able to use mathematics special knowledge to identify students' mistakes in solving math problems." A sample question for PCK-G was, "I am able to identify the rationale when students are creating new ways to solve math problems."

TPACK-MT is ranked on a 6-point scale, ranging from 1 (does not apply), 2 (applies slightly), 3 (somewhat applies), 4 (fairly applies), 5 (mostly applies), to 6 (completely applies; Graham et al., 2009). The junior high school mathematics teachers relied on their perceptions to select the most appropriate answers. The mean scores represent the level of knowledge.

We conducted the pilot test on 66 mathematics teachers from 10 schools. The number of returned responses was 63 (the return rate was 96.9%), with 62 valid for further analysis. Based on the item analysis results, we removed questions that include (a) a coefficient of skewness greater than 1 or less than –1, (b) a correlation of more than .75, (c) a subscale correlation less than .30, (d) factor loading values less than .30, or (e) a critical value (CR) that did not reach a significance of .05 (Costello & Osborne, 2005). Consequently, 35 items remained for testing.

Data analysis

To develop the reliability and validity of the TPACK-MT survey tool, we used SEM for confirmatory factor analysis. We first built an initial model on the basis of Mishra and Koehler (2006) framework. Then, we used the sample data to define the model and modified it in the light of parameter estimation results. Finally, to ensure the model stability, we used another group of sample teachers to cross-validate the model. We also used the *t* test and two-way MANOVA to explore age, teaching experience and technology integration interactions in junior high school mathematics teachers' TPACK in Taiwan.

Results

Instrument development

We followed the procedures by Lou, Lin, and Lin (2013), and employed 230 female teachers for the calibration sample and 294 male teachers for the validation sample. We used LISERL8.80 for confirmatory factor analysis, and maximum likelihood (ML) for parameter estimation to examine the validity. The observation variables numbered 35 items, and seven latent factors were for model validation.

Based on the goodness-of-fit statistics (GFI) results, the calibration sample and validation sample fitness indices were acceptable. The normed chi-square (χ^2/df) of the calibration sample was 2.33 (1218.74/524), and that of the validation sample was 2.38 (1246.46/524). When χ^2/df was between 2 and 3, the model was typically a good fit. Furthermore, according to Hu and Bentler (1999), the Comparative Fit Index (CFI) and the root mean square error of approximation (RMSEA) are required for inclusion in the description. They indicated that when the CFI is more than .90 and the RMSEA is less than.05, this means that the model has a good fit, and less than .08 means that the model has a reasonable fit. Therefore, in this study, the CFI in the calibration sample was .97, the RMSEA was .076, and the validation sample had a CFI of .98 and an RMSEA of .065, indicating that the measured model had a reasonable fit.

For cross-validation, LISERL provides an Expected Cross-Validation Index (ECVI) for measuring whether models can be used in different samples with a good fit (Browne & Cudeck, 1993). Because no fixed value exists for the ECVI, we used an independence model and a saturated model for comparison. It would be better if the EVCI is smaller than the independence model and the saturated model. The calibration sample model EVCI was 6.25, with 90% CI at (5.82, 6.71), and the independence model ECVI was 103.55, with the saturated model ECVI at 5.50. The EVCI of the calibration sample was more than that of the saturated model, but considerably less than that of the independence model. Regarding the validation sample model, the EVCI was 4.92 with 90% CI of (4.63, 5.43), and the EVCI of the independence model and the saturated model was 110.49 and 4.30, respectively. The validation sample model EVCI was more than that of the saturated model, but less than that of the independence model; therefore, the model had acceptable cross-validity.

Table 2 shows that all of the factor loadings (standardized validity coefficients) of the observed variables to the latent variables in the calibration sample were between .48 and .97, mostly meeting the requirement (between .95 and .50), and all the *t* values were greater than 1.96. This means that each observed variable reached a significance level of .05, and that the latent factors in the calibration sample had validity. The composite reliability between .676 and .944 was more than .6 for all the variables, showing that the model had good internal quality. The average variance extracted (AVE) values were between .401 and .774, which also met the requirements.

Table 2 Validity and Reliability of Calibration Sample and Validation Sample in TPACK-MT

N=526

Item	Standardized validity coefficient		Reliability coefficient		Composite reliability		Average variance extracted	
	C	V	C	V	C	V	C	V
CK1 Understand mathematics knowledge structures and approaches	.87	.85	.76	.72				
CK2 Understand related theories and the curriculum-developing process in the junior high school mathematics curriculum	.80	.82.	.64	.67				
CK3 Understand mathematics concepts in the junior high school mathematics curriculum	.84	.89	.71	.79				
CK4 Know the Grades 1-9 Curriculum competence indicators	.63	.69	.40	.48				
					.868	.888	.625	.667
PK1 Appraise students' learning progress	.70	.67	.49	.45				
PK2 Improve student motivation	.74	.77	.55	.59				
PK3 Use appropriate instructional methods to meet different students' needs	.68	.77	.46	.59				
PK4 Adapt teaching based on what students currently understand or do not understand	.73	.76	.53	.58				
PK5 Guide students to adopt appropriate learning strategies	.75	.81	.56	.66				
PK6 Assess students' learning in multiple ways	.74	.82	.55	.67				
PK7 Evaluate students' understanding of course content	.68	.64	.46	.41				
					.881	.900	.515	.515
TK1 Use emerging technology	.67	.76	.45	.58				
TK2 Use new computer applications	.63	.69	.40	.48				
TK3 Solve my own technology problems	.51	.78	.26	.61				
TK4 Keep up with emerging technological products and knowledge	.71	.85	.50	.72				
					.726	.854	.401	.596

PCK1 Use special mathematics knowledge to identify students' mistakes in solving math problems	.69	.65	.48	.42				
PCK 2 Identify the rationale when students try new ways to solve mathematics problems	.71	.66	.50	.44				
PCK 3 Explain the rationale behind the mathematics problem-solving process for students	.83	.83	.69	.69				
PCK 4 Use appropriate examples to explain mathematical concepts	.86	.88	.74	.77				
PCK 5 Use appropriate figures and tables to explain mathematical concepts	.79	.82	.62	.67				
					.883	.881	.604	.599
TCK1 Know the problems that students might encounter when they use technology in learning	.60	.61	.36	.37				
TCK2 Use appropriate technological tools to teach mathematics, and allow students to apply mathematics knowledge in their daily life	.81	.78	.66	.61				
TCK3 Use appropriate technology and instructional methods	.79	.79	.62	.62				
TCK4 Guide students to use ICT to analyze data	.79	.83	.62	.69				
TCK5 Guide students to use ICT to construct knowledge	.87	.92	.76	.85				
TCK6 Guide students to use ICT to engage in collaborative learning	.91	.90	.83	.81				
TCK7 Guide students to use ICT to evaluate their understanding and obstacles	.90	.91	.81	.83				
TCK8 Reflect on how ICT might impact my teaching	.89	.92	.79	.85				
					.944	.929	.680	.701
TPK1 Know specific computer software to help students understand mathematical concepts (e.g., PowerPoint, GSP, drawing pad, smart board)	.72	.80	.52	.64				
TPK2 Choose e-learning materials to add in mathematics class	.48	.60	.23	.36				
TPK3 Develop or revise existing e-learning materials to fit in the national curriculum guideline	.71	.75	.50	.56				
					.676	.762	.417	.520
TPACK1 Help other mathematics teachers use ICT in their classes	.78	.83	.61	.69				
TPACK2 Integrate mathematics content, instructional methods, and technology in teaching the junior high school mathematics curriculum	.96	.96	.92	.92				
TPACK3 Combine mathematics content, instructional methods, and technology to help students learn mathematics	.97	.95	.94	.90				
TPACK4 Evaluate student learning outcomes based on mathematics content, instructional methods, and technology	.79	.81	.62	.66				
					.932	.938	.774	.791

Source: This study.

Note: C= calibration sample, V= validation sample

Regarding the validation sample group, all of the factor loadings (standardized validity coefficients) of the observed variables to latent variables were between .60 and .96. The *t* values were more than 1.96, and reached a significance level of .05. These results show that all of the observed latent variables had good validity. The composite reliability (between .762 and .938) was higher than .7, and thus considered excellent. The AVE values in seven latent variables were between .515 and .791, which fit the requirement. In summary, both the calibration model and the validation model have a good fit, which means that the observed variables adequately reflect the latent variables. The first-order confirmatory factor analysis results are shown in Table 2.

TPACK-MT analysis

The means of the seven subscales were between 3.89 and 5.13, and the standard deviations (SD) were between .59 and .92. The descriptive statistics analysis results showed that the skewness of the seven subscales was between –.59 and –.467, and kurtosis was between –.329 and .499; thus, both fit the normal distribution hypothesis. Therefore, we used the maximum likelihood method (ML) to measure parameter estimations, and to identify the model fit for the measurement model. The descriptive statistics analysis results of the subscales and total scales are listed in Table 3.

Table 3 Descriptive Data Results of TPACK-MT Subscales

N=526

Subscale	Mean	SD	Skewness	Kurtosis
CK	5.04	.67	–.435	–.195
PK	4.88	.59	–.366	.486
TK	4.30	.92	–.336	.159
PCK	5.13	.59	–.454	–.087
TPK	3.89	.89	–.422	.499
TCK	4.29	.85	–.275	–.080
TPACK	5.05	.92	–.467	.359
Overall	4.50	.58	–.059	–.329

Source: This study.

Internal consistency reliability

Table 4 shows the TPACK survey and the internal reliability of the seven subscales. The seven subscales' Cronbach's α values were between .77 and .955, and the overall Cronbach's α was .956. The standardized Cronbach's α values were between .771 and .955, and the overall Cronbach's α was .956. The internal validity was high, and indicated adequate internal reliability.

Table 4 TPACK Scales and 7 Subscales' Cronbach's α N=526

Subscale	Cronbach's α	Standardized cronbach's α	Item
CK	.877	.880	4
PK	.906	.908	7
TK	.861	.869	4
PCK	.888	.890	5
TPK	.955	.955	8
TCK	.770	.771	3
TPACK	.891	.895	4
Overall	.956	.956	35

Source: This study.

Internal consistency validity

Table 5 shows the correlation coefficient of the seven subscales and overall TPACK scales. The coefficients were between .193 and .855, and all reached significance, indicating that the survey tool has good internal validity.

Table 5 Correlation among TPACK-MT Subscales and Overall Scale N=526

	CK	PK	TK	PCK	TPK	TCK	TPACK	Overall
CK	-	.659***	.263***	.723***	.267***	.316***	.307***	.607***
PK		-	.382***	.696***	.392***	.389***	.397***	.718***
TK			-	.280***	.661***	.652***	.613***	.759***
PCK				-	.193***	.296***	.219***	.577***
TPK					-	.731***	.821***	.855***
TCK						-	.791***	.808***
TPACK							-	.833***

Source: This study.
***p<.001

The results of TPACK, TPK and TCK subscales were highly correlated; there might be some concerns about multicollinearity. To avoid the multicollinearity problem, we can use composite reliability to assess the fitness of the calibration model. Fornell and Larcker (1981) suggested that when the composite reliability is more than .6, the observed variables can reflect latent variables. The composite reliability of latent variables in this study were more than .6, which means that latent variables have high correlations, and did not affect the fitness of model.

Gender and age effects on mathematics teachers' TPACK

We employed two-way MANOVA to analyze the effects of gender and age on mathematics teachers' TPACK. The results showed that no significant interactive effect exists, but the main effects of gender and age were significant. Gender effects yielded significant differences on TK (F=5.20, p=.010), and showed that male teachers' TK scored higher than that of female teachers. Regarding age, five subscales and overall scales (F=6.077, p=.002) had significant differences. The five subscales were CK (*F*=3.916, *p*=.021), TK (*F*=14.796, *p*=.000), TPK (*F*=5.430, *p*=.005), TCK (*F*=7.556, *p*=.001), and TPACK (*F*=7.482, *p*=.001). The post hoc results of each subscale and overall scale are shown in Table 6. We found that male mathematics teachers had a higher TK score, and teachers who were younger than 30 years had a higher score in TK, TPK, TCK and TPACK.

Table 6 MANOVA Results of Subscales and Overall Scale in Gender*Age

N=524

Independent var.	Dependent var.	*df*	*F*	*p*	η^2	*Post Hoc*
gender	CK	1	.299	.585	.001	-
	PK	1	.139	.709	.000	-
	TK	1	5.200*	.023	.010	male>female
	PCK	1	.018	.894	.000	-
	TPK	1	.821	.365	.002	-
	TCK	1	1.697	.193	.003	-
	TPACK	1	.508	.476	.001	-
	overall	1	1.412	.235	.003	-
age	CK	2	3.916*	.021	.015	above 41yr.>31-40yr.
	PK	2	1.378	.253	.005	-
	TK	2	14.796***	.000	.054	under 30yr.>31-40yr.> above 41yr.
	PCK	2	.440	.645	.002	-
	TPK	2	5.430**	.005	.021	under 30yr.>31-40yr. under 30yr.>above 41yr.
	TCK	2	7.556**	.001	.028	under 30yr.>31-40yr> above 41yr
	TPACK	2	7.482**	.001	.028	under 30 yr >31-40yr under 30yr.>above 41yr
	overall	2	6.077**	.002	.023	under 30yr.>31-40yr. under 30yr.>above 41yr.
gender *age	CK	2	.936	.393	.004	-
	PK	2	1.070	.344	.004	-
	TK	2	.024	.976	.000	-
	PCK	2	.961	.383	.004	-
	TPK	2	1.744	.176	.007	-
	TCK	2	1.013	.364	.004	-
	TPACK	2	2.583	.077	.010	-
	overall	2	1.786	.169	.007	-

Source: This study.
*p<.05, **p<.01, ***p<.001

Gender and seniority effects on math teachers' TPACK

The two-way MANOVA results showed that no significant interaction effect exists, but the main effects of gender and teaching experience were significant. Gender effects were found on TK (*F*=7.338, *p*=.007), TPK (*F*=5.484, *p*=.020), TCK (*F*=4.134, *p*=.043), TPACK (*F*=6.884, *p*=.009), and the overall scale (*F*=6.119, *p*=.014). Male mathematics teachers had higher scores than their female counterparts on the four technology-related subscales and the overall scale. Regarding teaching experience, all seven subscales, CK (F=5.041, p=.007), PK (F=4.453, p=.012), TK (F=15.576, p=.000), PCK (F=6.356, p=.002), TPK (F=6.407, p=.002), TCK (F=12.212, p=.000), and TPACK (F=7.214, p=.001), as well as the overall scale (F=6.474, p=.002), had significant differences. From the post hoc test, we found that mathematics teachers with less than 10 years of teaching experience had a higher score in all four technology related subscales and overall scale. Teacher with more than 21 years teaching experiences had highest score in CK, and lowest scores in TK, TCK and TPACK. The post hoc test results of each subscale and the overall scale are shown in Table 7.

Table 7 MANOVA Results of Subscales and Overall Scale in Gender* Teaching Experience

N=524

Independent var.	Dependent var.	*df*	*F*	*p*	η^2	*Post Hoc*
gender	CK	1	1.234	.267	.002	-
	PK	1	1.293	.256	.002	-
	TK	1	7.338*	.007	.014	male>female
	PCK	1	.164	.685	.000	-
	TPK	1	5.484*	.020	.010	male>female
	TCK	1	4.134*	.043	.008	male>female
	TPACK	1	6.884**	.009	.013	male>female
	overall	1	6.119*	.014	.012	male>female
teaching experiences	CK	2	5.041**	.007	.019	above 21yr.> 0-10yr. above 21yr.>11-20yr.
	PK	2	4.453*	.012	.017	above 21yr.> 11-20yr.
	TK	2	15.576***	.000	.057	0-10yr.> 11-20yr. 0-10yr.> above 21yr.
	PCK	2	6.356**	.002	.024	above 21yr.> 11-20yr.
	TPK	2	6.407**	.002	.024	0-10yr.> 11-20yr. 0-10yr.> above 21yr.
	TCK	2	12.212***	.000	.045	0-10yr.> 11-20yr. 0-10yr.> above 21yr.
	TPACK	2	7.214**	.001	.027	0-10yr.> 11-20yr. 0-10yr.> above 21yr.
	overall	2	6.474**	.002	.024	0-10yr.>11-20yr. 0-10yr.> above 21yr.
gender * teaching experiences	CK	2	.987	.373	.004	-
	PK	2	.289	.749	.001	-
	TK	2	1.111	.330	.004	-
	PCK	2	.799	.450	.003	-
	TPK	2	.770	.464	.003	-
	TCK	2	2.552	.079	.010	-
	TPACK	2	1.108	.331	.004	-
	overall	2	1.337	.263	.005	-

Source: This study.
$^{*}p$<.05, $^{**}p$<.01, $^{***}p$<.001

Gender and technology effects on mathematics teachers' TPACK

Regarding the interaction between gender and technology integration, the two-way MANOVA results showed that PCK (F=4.122, p=.043), TCK

(F=6.818, p=.009), and the overall scale (F=3.903, p=.049) had a significant interactive effect, as shown in Table 8. Therefore, we further examined the simple main effects of gender and technology integration. Table 9 shows that male mathematics teachers' TCK (F=54.620, p=.000) and the overall scale (F=22.239, p=.000) had significant differences (Will's Λ=.835, p=.000). This means that male teachers with technology integration experience had higher TCK and overall scale scores than those with no technology integration experience. For female mathematics teachers Will's Λ=.893 (p=.000), PCK (F=4.749, p=.030), TCK (F=12.939, p=.000), and the overall scale (F=4.189, p=.042) had significant differences. The post hoc test results show that female teachers with technology integration experience had higher scores than those without technology integration experience in TCK and the overall scale. Yet, female teachers with no technology integration experience had a higher score than those who had technology integration experience in the PCK subscale.

Regarding technology integration experiences, PCK (F=4.029, p=.045), TCK (F=7.842, p=.005), and the overall scale (F=8.008, p=.005) had significant differences (Will's Λ=.976, p=.029), and male mathematics teachers had higher scores than their female counterparts. For teachers with no technology integration experiences, PCK, TCK, and the overall scale did not yield significant differences.

Table 8 Two-way MANOVA Results of Seven Subscales and Overall Scale in Gender* Technology Integration

N=524

Independent var.	Dependent var.	*df*	*F*	*p*	η^2
gender * technology integration	CK	1	.996	.319	.002
	PK	1	.961	.327	.002
	TK	1	.749	.387	.001
	PCK	1	4.122^{**}	.043	.008
	TPK	1	3.223	.073	.006
	TCK	1	6.818^{***}	.009	.013
	TPACK	1	1.673	.196	.003
	overall	1	3.903^{*}	.049	.007

Source: This study.
$^{*}p<.05$, $^{**}p<.01$, $^{***}p<.001$

Table 9 Simple Main Effect Results of Seven Subscales and Overall Scale in Gender* Technology Integration

source	*df*	Λ	*F*		
			PCK	TCK	overall
technology integration					
In male	1	$.835^{***}$	.594	54.620^{***}	22.239^{***}
In female	1	$.893^{***}$	4.749^{*}	12.939^{***}	4.189^{*}
gender					
In with	1	$.976^{*}$	4.029^{*}	7.842^{**}	8.008^{**}
In without	1	.969	1.249	1.559	0.272

Source: This study.
$^{*}p<.05$, $^{**}p<.01$, $^{***}p<.001$

Discussion

Validity and reliability of TPACK-MT

The TPACK framework has been discussed for many years; considerable effort has been devoted to improving teachers' TPACK. In this paper, we developed a TPACK survey for junior high school mathematics teachers. We designed TPACK-MT based on Mishra and Koehler's (2006) TPACK framework, and derived seven subscales totaling 35 items. The mean scores of all the subscales were between 3.89 and 5.13, and the SD were between .59 and .92. The instrument has good internal validity and reliability. Furthermore, we used a calibration sample for first-order confirmatory factor analysis, and the results showed that the composite reliability of the seven-factor model were between .676 and .944, with all values larger than .6. This means that the observed variables reflect latent variables, and have excellent reliability. In addition, we used a validation sample to examine all the indices for goodness of fit. The developed survey tool fits Mishra and Koehler's (2006) seven-factor TPACK model, and has been verified for validity and reliability. The study results are consistent with Lin et al. (2013) study and supported the seven-factor TPACK model. Previous studies focused on the pre-service teachers' TPACK, most survey items were general to all subjects, and some of factors (e.g. TPK, TCK) might not be distinguished by preservice teachers (Chai et al., 2011; Koh et al., 2010). This finding also supported the viewpoint of contextualized TPACK in a particular lesson topic and instructional activities (Cox & Graham, 2009).

Mathematics teacher's TPACK

The MANOVA results showed that male teachers scored higher in TK, TPK, TCK, and TPACK compared with female teachers. In addition, male teachers with experience in technology integration had higher PK and TCK scores than their female counterparts with experience in technology integration. The study results are consistent with previous studies that have shown that female teachers had lower TK scores than male teachers (e.g., Koh et al., 2010; Lin et al., 2013). Several studies found that female teachers were less confident to use ICT in learning and teaching and tend to indicate little or some confidence when self-check ICT competence compared to male teachers (e.g., Jamieson-Proctor, Burnett, Finger, & Watson, 2006).

Regarding age differences, we found that teachers under 30 years of age had higher TK, TPK, TCK, and TPACK scores than other groups. Similar results were also found in seniority. Novice teachers with less than 10 years of teaching experience had highest scores on the four technology-related knowledge bases (i.e., TK, TCK, TPK and TPACK) than other groups. Experienced teachers with

21 years or more of teaching experience had lower scores on four technology related knowledge, but had higher CK, PK, and PCK scores than other groups. This result is consistent with Lin et al. (2013), and Jang and Tsai (2012) that experiences had negative correlation with teachers' TPACK.

The results show that young teachers were more familiar with technology use in teaching and learning. One possible reason is that experienced teachers who are more familiar with subject content and student needs might consider technology integration to be a pedagogical strategy (Graham, 2011; Shulman, 1986). Whereas the educational goals in junior high school mathematics emphasize the representation of abstract concepts, other concrete hands-on models are available for students to observe and manipulate physically; technology might not be the only path to attaining goals. Therefore, experienced teachers might not pay particular attention to emerging technologies and related knowledge.

Conclusion and Implication

In this study, we developed and validated an instrument, TPACK-MT, to assess in-service mathematics teachers' technological pedagogical content knowledge. From the CFA results, the instrument showed good validity and reliability of the TPACK-MT, hence, it supported the Mishra and Koehler's (2006) seven-factor model of TPACK. This instrument could be further used to assess both pre-service and in-service mathematics teachers' TPACK, and help teacher educators to develop professional development programs for mathematics teachers.

The survey results show the female teachers rated lower confidence in TK, TPK, TCK and TPACK. It is suggested that female teachers need more opportunities to explore technology-related activities. Teacher educators could organize workshops or professional communities for female teachers to share knowledge and practice on content-general technology (TK), content-specific technology (TCK), or pedagogical-general technology (TPK). Eventually, female teachers could increase their confidence on technology-related knowledge and improve their TPACK as well.

We also found that novice teachers with 10 year or less teaching experiences had higher technology-related knowledge, while experienced teachers with 21 or more years had lower technology-related knowledge. It is suggested that teacher educators and authorities may provide diverse professional development opportunities, including formal and informal support for teachers in different career stages. Researchers found that beginning teachers might need informal professional development opportunities, such as collaborations with other teachers, the exchange of ideas, and opportunities to observe other classrooms, while mid-career teachers may incline to formal learning opportunities, such as institutions providing training programs (Richter et al., 2011). Teachers in different stages might be benefit from diverse professional develop programs. Further studies maybe explore teachers' orientation and TPACK changes over career stages.

The purpose of the study is to develop and validate a TPACK assessment instrument for junior high school mathematics teachers. It is hoped that results of this study could shed light on our understanding of in-service mathematics teachers' technological pedagogical content knowledge with the ultimate aim of improving mathematics teachers' technology integration. Future studies may explore teachers' beliefs, ICT practices and contexts when developing teachers' TPACK.

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Ting-Ling Lai ORCID 0000-0003-3579-1917
Hsiao-Fang Lin ORCID 0000-0003-0673-8826

教育資料與圖書館學　52 : 1 (Winter 2015) : 59-82
DOI:10.6120/JoEMLS.2015.521/0642.RS.CE

研究論文

國中數學教師科技學科教學知識之探究

賴婷鈴[a*]　林曉芳[b]

摘要

本研究目的旨在發展評量國中數學教師科技學科知識（TPACK）之工具，量表架構乃根據Mishra和Koehler（2006）所提出之科技學科知識模式，此理論模式著重於國中數學教師之學科與教學知識論述。本研究調查台灣526位國中數學教師，以驗證性因素分析建立量表之信度與效度，利用建模樣本（N=230）評鑑測量模式是否與實徵資料相互適配，再以驗證樣本（N=294）驗證其模式之適配性；根據驗證性因素分析結果顯示模式適配度良好，確認本研究模式的確具有良好信效度。另又以多變量變異數分析探討國中數學教師在性別、年齡、年資及科技使用在科技學科知識的差異，文末就量表編製之結果及未來研究方向提出建議。

關鍵詞：科技學科知識，國中數學，驗證性因素分析

[a]淡江大學教育科技系助理教授
[b]明道大學課程與教學研究所助理教授
*本文主要作者兼通訊作者：tlai@mail.tku.edu.tw