Exploring the TPACK of Taiwanese secondary school science teachers using a new contextualized TPACK model

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Technological pedagogical and content knowledge (TPACK) has been one of the steering theoretical concepts widely employed by researchers in order to examine and develop teachers' knowledge of integrating technology into teaching. Existing research on TPACK shows little about in-service secondary school science teachers' TPACK through a quantitative approach. The purposes of this study were to explore TPACK of secondary school science teachers using a new contextualized TPACK model. Associations between in-service teachers' TPACK and other factors were also examined. The TPACK questionnaire was mailed to secondary schools randomly selected across different parts of Taiwan, and return envelopes were provided for completed questionnaires. There were 1292 science teachers from secondary schools for factor analysis. An independent samples *t*-test was conducted when there were two groups (i.e., gender) to be compared for TPACK. ANOVA was conducted when there were more than two groups (i.e., science teaching experience) compared for TPACK. The results indicated that secondary science teachers' TPACK was statistically significant according to gender and teaching experience. With the consideration of other TPACK sub-components, male science teachers rated their technology knowledge significantly higher than did female teachers. Experienced science teachers tended to rate their content knowledge and pedagogical content knowledge in context (PCKCx) significantly higher than did novice science teachers. However, science teachers with less teaching experience tended to rate their technology knowledge and technological content knowledge in context (TPCKCx) significantly higher than did teachers with more teaching experience. The study shows how gender and teaching experience were influential factors for secondary school science teachers' TPACK. The research implications of this study are provided along with suggestions.

Introduction

The U.S. Department of Education proposed the *Education Through Technology Act of 2001* to indicate the importance of effective uses of technology integrated into curricula and instruction in both elementary and secondary schools in terms of increasing students' academic achievements (U.S. Department of Education, 2001). Instructional technology has become an essential trend in educational reform. As part of this process, school teachers have been encouraged to adopt different technological tools and develop their literacy of technology, content, and pedagogy for the enhancement of professional development and teaching effectiveness by using technological devices.

Researchers have stressed the importance of effective use of technology in scientific teaching and learning (McFarlane & Sakellariou, 2002; Rodrigues, Marks, & Steel, 2003; Rogers, 2004). Through the use of technology, students' scientific investigations and reasoning can be constructively developed and help students connect constructed knowledge to practical work (McFarlane & Sakellariou, 2002). Students indicate higher interests in learning strategies related to computers (La Velle, McFarlane, & Brawn, 2003). Additionally, the utilization of technology can help improve teachers' attitudes, confidence, and instructional applications (Sorensen, Twidle, Childs, & Godwin, 2007), help teachers reflect upon scientific explanations and examples generated in their teaching (La Velle et al., 2003), and understand scientific concepts and creativity (Jang, 2009; Rodrigues et al, 2003). On the contrary, lack of the knowledge about utilizing technology can limit the effectiveness of integrating technology into teaching (Barak, 2007). Therefore, teachers' knowledge to integrate content, pedagogy and technology has become important.

To fully understand the complexity of literacy in relation to content, pedagogy, and technology, researchers have employed a theoretical framework, technological, pedagogical and content knowledge (TPACK), to examine this particular type of knowledge through various dimensions. TPACK originated from the pedagogical content knowledge (PCK) framework proposed by Shulman (1986). PCK depicts knowledge at the intersection between content and pedagogy (Angeli & Valanides, 2009; Cox & Graham, 2009; Mishra & Koehler, 2006; Schmidt et al., 2009). Mishra and Koehler (2006) proposed the TPACK framework and stated that the central construct of TPACK, represents an emerging form of transformative knowledge through an integrative process generated from the existing instructional forms into new forms that potentially maximize the effectiveness of integrating technology into teaching. Researchers have widely adopted the model to develop TPACK surveys for examining teachers' development of this particular knowledge (Archambault & Barnett, 2010; Chai, Koh, & Tsai, 2010, 2011; Koehler & Mishra, 2005; Sahin, 2011; Schmidt et al., 2009). It has become a guiding framework to help teachers develop their integrative knowledge of content, pedagogy, and technology with use of technological tools (Lee & Tsai, 2010; McGrath, Karabas, & Willis, 2011).

Researchers have employed the TPACK framework in science classrooms and different variables have been examined with TPACK such as teachers' self-efficacy (Lee & Tsai, 2010) and skills of integrating technology into teaching (Allan, Erickson, Brookhouse, & Johnson, 2010; Guzey & Roehrig, 2009; Jang, 2010; Jang & Chen, 2010). In- and pre-service science teachers' TPACK has been examined through a questionnaire in which the correlations between the seven TPACK sub-components were examined (Lin, Tsai, Chai, & Lee, 2013). In-service science teachers' TPACK was developed by integrating interactive white boards (IWBs) into facilitating students' understanding and teachers' representation and instructional strategies (Jang, 2010). Science teachers' TPACK was found to relate to school context and their reasoning skills (Guzey & Roehrig, 2009). Trautmann and MaKinster (2010) concluded that training using geospatial technology helped science teachers improve their TPACK, and helped to develop their skills in designing technology integrated curricula and the evaluation of the effectiveness of curricular lessons. The review of research on TPACK in science classrooms suggests that science teachers could develop their TPACK through using technological tools in science teaching. However, current research on TPACK in science classrooms lacks an understanding primarily for in-service secondary school science teachers' TPACK through a quantitative approach.

Researchers have begun to show an interest in differences of teachers' TPACK by gender (Erdogan & Sahin, 2010; Jang & Tsai, 2012; Lin et al., 2013) and teaching experience (Jang & Tsai, 2012; Lee & Tsai, 2010) and have revealed various findings. The difference of the findings from the current empirical studies may show that researchers may receive different results when conducting TPACK research in a different research context or with a different group of participants. Therefore, the primary purpose of the study was to use a TPACK questionnaire developed by Jang and Tsai (2012) for a group of secondary school science teachers. As the TPACK questionnaire was developed with elementary school science and mathematics teachers with the use of IWBs and resulted in four sub-components as a new contextualized TPACK model (Jang & Tsai, 2012), it is unknown if the use of the questionnaire in a different context (i.e., in-service secondary school science teachers) could result in the same number of sub-components in the TPACK model. Additionally, secondary school science teachers' TPACK by gender and science teaching experience were addressed to complement the insufficiency of TPACK research in gender and teaching experience.

Purposes of this study

This study was conducted to examine the TPACK of in-service secondary school science teachers by employing a TPACK questionnaire developed by Jang and Tsai (2012). The data obtained in the study were analysed to understand whether the TPACK model originally developed for elementary school teachers could be appropriately applied in the secondary school context in Taiwan. Differences in science teachers' TPACK were also examined according to gender and teaching experience.

Research questions

Based on the purposes of the study, we proposed two research questions:

1. Is the developed TPACK model effectively employed in the context of secondary school science teachers?

2. Does the TPACK of secondary school science teachers differ according to gender and teaching experience?

Literature review

The TPACK conceptual framework

Shulman (1986) claimed when studying teachers' knowledge of professional development, we should combine the domains of content and pedagogy, rather than looking at each particular domain separately. He further proposed the PCK model consisting of pedagogical knowledge (PK), content knowledge (CK), and pedagogical content knowledge (PCK). The concept of technological pedagogical and content knowledge (TPACK) was generated from PCK framework developed by Shulman (Angeli & Valanides, 2009; Cox & Graham, 2009; Mishra & Koehler, 2006; Mishra & Koehler, 2009; Niess et al., 2009; Schmidt et al., 2009), which refers to technological knowledge contextually situated within content, pedagogical knowledge, and the interrelated knowledge between the two. Pamuk (2012) conducted a qualitative study to examine pre-service teachers' development of TPACK and concluded that before teachers are able to integrate technology, they must prioritize their development of pedagogical content knowledge from their teaching experiences. This finding verifies the usefulness of the TPACK model which is primarily built on the PCK model.

Koehler and Mishra (2005) proposed a TPCK framework that contains three core types of knowledge: content knowledge (CK), pedagogy knowledge (PK, and technology knowledge (TK), and four interrelated types of knowledge between the three core types of knowledge: PCK, technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPCK). The contextualized knowledge includes teachers' knowledge of their students' prior knowledge and learning difficulties, how to interact with students, and evaluating students' learning (Grossman, 1990; Tamir, 1988). Researchers have suggested the importance of integrating contextualized-knowledge of students' specific learning difficulties and conceptions into the initial TPACK model to make the model more complete.

The TPACK model has been widely used in both quantitative (Archambault & Barnett, 2010; Chai et al., 2010; Jang & Tsai, 2012; Koh, Chai, & Tsai, 2010) and qualitative research studies (Harris & Hofer, 2011; McGrath et al., 2011; Pamuk, 2012). Additionally, researchers have shown an interest in examining knowledge of integrating technology into teaching for both pre-service (Hardy, 2010; Lee & Hollebrands, 2008; Özgün-Koca, Meagher, & Edwards, 2010) and in-service teachers (Trautmann & MaKinster, 2010). In recent years, the TPACK model has also been employed to develop teachers' professional development according to different learning contexts such as mathematics (Niess et al., 2009) and science (Graham et al., 2009). A number of TPACK surveys have been developed with different groups of participants including pre-service (Chai et al., 2010, 2011; Chai, Koh, Tsai, & Tan, 2011; Koehler & Mishra, 2005; Koh et al., 2010; Sahin, 2011; Schmidt et al., 2009) and in-service teachers (Archambault & Barnett, 2010; Jang & Tsai, 2012). A different number of TPACK sub-components have been found, expanding upon the initial seven TPACK sub-components of the TPACK (Chai, Koh, & Tsai, 2010; Chai, Koh, Ho, & Tsai, 2012; Jang & Tsai, 2012). Other researchers have added different domains such as assistive technology and instructional technology (Marino, Sameshima, & Beecher, 2009), as well as design, exertion, ethics, and proficiency (Yurdakul et al., 2012) in the TPACK model, to explore the in-depth TPACK of pre-service teachers in contextualized learning environments.

Developing a new contextualized TPACK model

The current TPACK framework, consisting of seven components, has been employed in a number of studies (Archambault & Barnett, 2010; Chai, Koh, &Tsai, 2011). However, researchers have argued about how to distinguish between the components of TCK, TPK, and TPCK. Although these components are clearly defined, it is challenging to discriminate one from the other when it comes to the natural form of TPACK knowledge (Angeli & Valanides, 2009; Archambault & Barnett, 2010; Chai et al., 2011; Graham, 2011). Researchers must hold sufficient understanding of PCK before they can systematically understand and accurately measure TPACK constructs. Though TPACK has evolved from PCK, the current TPACK model does not emphasize the crucial components originated from the PCK framework (Grossman, 1990; Magnusson, Krajcik, & Borko, 1999; Shulman, 1987), which comprises knowledge of students' understanding and use of assessment. Therefore, a TPACK model has been developed along with a TPACK questionnaire to take science and mathematics teachers' contextualized-knowledge of learners' prior knowledge and learning difficulties into consideration (Jang & Tsai, 2012). This TPACK model not only contains core elements of PCK (i.e., CK, PK, and PCK), but also considers learners' prior knowledge and learning difficulties in the science-related contexts.

The contextualized TPACK model is finalized with four TPACK sub-components as the components of PK and PCK are loaded into the component, pedagogical content knowledge in context (PCKCx), whereas the components of TPK, TCK and TPCK are loaded into the component, technological content knowledge in context (TPCKCx) (Jang & Tsai, 2012). The results lead this TPACK model with the consideration of contexts and address an explanation for the challenge of discriminating several obscure components related to technology within the initial TPACK model (Jang & Tsai, 2012). Therefore, this TPACK model has advantages in these respects. One of the primary goals of this study was to illustrate that it is imperative to use empirical data when constructing the understanding of the TPACK constructs and clarifying the definitions and boundaries between the TPACK sub-components. Therefore, we proposed a new TPACK model and define TPACK as "a teacher's integrated understanding of four components of CK, PCKCx, TK, and TPCKCx" (see Figure 1). The arrows in the model in Figure 1 represent the growth of TPACK as a result of new experiences and learning activities. From this perspective, the continuing growth of TPACK, as a result of new teaching experiences, constitutes its dynamic nature and justifies the change from PCK to TPACK (Jang & Chen, 2010). More detailed descriptions of the four categories are given as follows.

Content knowledge (CK)

Content knowledge in any subject refers to "the amount and organization of knowledge per se in the mind of the teacher" (Shulman, 1986, p. 9). This knowledge includes not only facts and concepts but also the structures and rules that incorporate those facts and concepts. Teachers must maintain a broad knowledge base of the subject matter so that they are able to retrieve and teach contents in logical and organized ways. Teachers' CK informs designs of horizontal and vertical curricula for a subject (Grossman, 1990), allows them to both differentiate between core and peripheral concepts, and implement course activities relevant to the course. In teaching practice, CK enables teachers to select course units appropriate to students, articulate key concepts and their relationships, and answer student questions correctly. In essence, CK provides the foundation for PCK. However, CK itself implies no fundamental difference between the subject matter knowledge of a teacher and that of a subject matter specialist or a scholar (Deng, 2007). The difference between teachers and subject matter specialists, in fact, lies in teachers' ability to transform CK into teachable and comprehensible formats (Shulman, 1986, 1987).

Pedagogical content knowledge in context (PCKCx)

PCK is the knowledge that science teachers use to transform their content knowledge and help their students develop a deep understanding of specific subject matter (Shulman, 1986). This subject specific knowledge results from an interaction among teachers' pedagogical knowledge, knowledge of context, and content knowledge (Grossman, 1990). During the transformation process, teachers elaborate on the components and key ideas of the subject content knowledge, identify various representations (e.g., analogies, illustrations, examples, explanations, demonstrations, and hints) of the concepts, and design curricula and activities for instruction (Shulman, 1987).

PCKCx is concerned with the representation and formulation of concepts, pedagogical techniques, knowledge of what makes concepts difficult or easy to learn, knowledge of students' prior knowledge, and theories of epistemology in specific contexts (Mishra & Koehler, 2006). Barnett and Hodson (2001) claimed that classroom life is complex and uncertain, and that "teachers, like all other learners, also have to integrate their understanding into the various social contexts in which they are located in ways that are socially acceptable" (p. 432). Science teachers must be familiar with the teaching context and be able to establish adaptive and open learning environments that promote student interactions and address student voices and needs.

Technology knowledge (TK)

With the advent of the 21st century, tools, communication, information, and the nature of work have changed dramatically as a result of advancement in technology (Niess, 2005). Accordingly, in the era of computer and internet technology, teachers must be aware of the affordance of computer and multimedia technologies and their potential for instruction. TK is knowledge about PowerPoint, multimedia, interactive whiteboards and more advanced technologies, such as the Internet, digital video, etc. This involves the skills required to operate particular technologies. TK includes knowledge of how to install and remove peripheral devices, install and remove software programs, and create and archive documents. Science teachers should have capabilities to use various technologies in teaching and learning settings, and additionally, know how teaching might change as a result of using particular technologies.

Technological pedagogical content knowledge in context (TPCKCx)

TPCKCx is conceptualized as a unique body of knowledge that makes a teacher competent at designing technology-enhanced teaching and learning in specific contexts. With knowledge and awareness of technology in mind, teachers are able to rethink course elements that are difficult to teach in traditional ways, and attempt to transform their instruction into better representations using technologies (Angeli & Valanides, 2009; Jang, 2008). On the other hand, for technology to be an integral part of teaching and learning, teachers must also "develop an overarching conception of their subject matter with respect to technology and what it means to teach with technology" (Niess, 2005, p. 510). At the heart of this conceptualization is the view that technology is not a delivery vehicle that simply delivers information, but a cognitive partner that amplifies or augments student learning. When content, pedagogy, and technology are well-integrated to facilitate students' knowledge construction in a specific context, teachers are well-equipped with TPACK, a consolidated knowledge system that promotes students' learning.

As stated by the new four dimensions in the TPACK theoretical framework, this study attempts to verify the new TPACK model in a different context by focusing on in-service secondary school science teachers in Taiwan. The TPACK questionnaire developed by Jang and Tsai (2012) was to examine elementary school science and math teachers' TPACK specifically through their use of the IWBs. Teachers using IWBs showed significantly higher TPACK than teachers not using IWBs. The differences between the four TPACK sub-components were also significantly different among the two groups. Therefore, we attempt to understand whether the questionnaire items from the previous study could be extracted with the same TPACK sub-components through factor analysis in a different context with secondary school science teachers. Teachers' TPACK was also examined by gender and teaching experience.

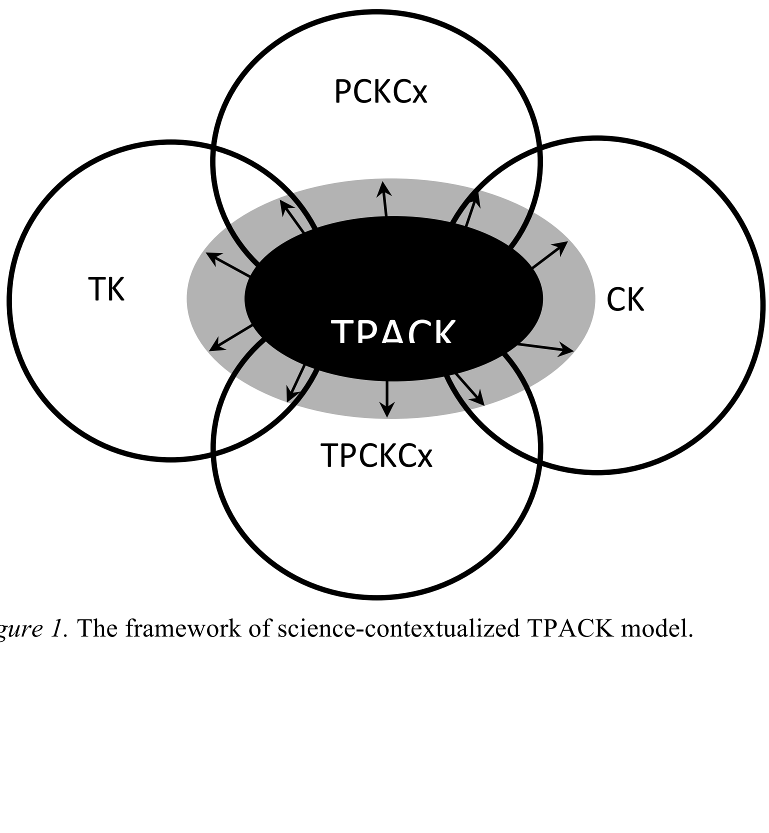

Figure 1. The framework of science-contextualized TPACK model.

Teachers' TPACK in science teaching

Researchers have conducted studies to examine teachers' TPACK development in science classrooms (Allan et al., 2010; Guzey & Roehrig, 2009; Hechter, 2012; Jang, 2010; Jang & Chen, 2010; Khan, 2011; Lin et al., 2013; Trautmann & MaKinster, 2010). Science teachers' TPACK has been examined through a TPACK questionnaire and the results indicated that teachers' perceptions on TPC correlated positively with the other six TPACK sub-components (i.e., TK, PK, CK, TCK, TPK, PCK, and TPC, Lin et al., 2013).

A variety of technological tools (e.g., interactive Probeware, mind-mapping tools, whiteboards, geospatial technology) have been used in science classrooms and teachers' integration of the technology into science teaching has been examined (Guzey & Roehrig, 2009; Jang, 2010; Trautmann & MaKinster, 2010). In-service science teachers used IWBs to facilitate students' understanding of the topic and present appropriate teaching strategies and representations, which ultimately developed teachers' TPACK (Jang, 2010). Guzey and Roehrig (2009) have examined in-service science teachers' TPACK through the use of various technological tools in a professional development program. The researchers concluded that school context and teachers' reasoning skills have influenced teachers' development of TPACK. In-service science teachers trained with using geospatial technology of teaching science topics developed their technological skills and ideas of using technological tools, which displayed their improvement of TPACK (Trautmann & MaKinster, 2010).

Research on TPACK in science classrooms suggests that science teachers could develop their TPACK through using technology in science teaching. A review of existing quantitative research in TPACK with science teachers reveals that only two empirical studies have been conducted to understand science teachers' TPACK. Lin et al. (2013) conducted a study with pre- and in-service science teachers in Singapore to examine their TPACK through a TPACK questionnaire that consists of seven sub-TPACK components. Jang and Tsai (2012) developed a TPACK questionnaire that consists of four sub-components in a TPACK model with elementary school science and mathematics teachers in Taiwan (see Figure 1). One of the claims for the new contextualized TPACK model made by Jang and Tsai (2012) was to take the context into consideration, meaning that teachers' TPACK might vary in different contexts. Therefore, the primary purpose of the study was to use the TPACK questionnaire developed by Jang and Tsai (2012) in a different context with secondary school science teachers, to verify whether the results could fit for the TPACK model comprising four sub-components.

Science teachers' TPACK by gender and teaching experience

There have been several empirical studies indicating teachers' difference on TPACK by gender (Erdogan & Sahin, 2010; Jang & Tsai, 2012; Lin et al., 2013). Erdogan and Sahin (2010) examined pre-service mathematics teachers' TPACK and found that male teachers' TPACK were significantly higher than female teachers. Lin et al. (2013) in their study found that female teachers were more confident in PK but less confident in TK compared to male teachers. Koh et al. (2010) examined pre-service teachers' TPACK and found gender difference on technological knowledge, content knowledge, and knowledge of teaching with technology. However, a different finding was presented in the study by Jang and Tsai (2012) who found that TPACK of elementary science and mathematics teachers indicated no significant gernder differences with the use of IWBs.

Research on TPACK by teaching experience suggests varying results as well. Lee and Tsai (2010) examined in-service teachers' TPACK on web-based knowledge and found that more experienced teachers perceived their TPACK with respect to the Web lower than less experienced teachers. However, Jang and Tsai (2012) found that more experienced elementary science and mathematics teachers' CK, PCKCx, TPCKCx and overall TPACK were significantly higher than less experienced teachers.

Through reviewing the empirical studies about TPACK by gender and teaching experience, research context and participant background might be the factors that vary the research findings. As current research shows little about whether secondary science teachers' TPACK differ by gender and teaching experience, one of the aims in the study was to examine whether science teachers showed significant differences on TPACK according to gender and science teaching experience.

Methodology

The questionnaire

The questionnaire used in this study was developed for a study of examining elementary science and math teachers' TPACK in relation to use or no use of IWBs by Jang and Tsai (2012). In the TPACK questionnaire of the current study, the personal information section was revised for the purposes of this study. The only difference between the TPACK items in the two questionnaires was that the term "interactive whiteboards" was changed to "computer technology." The reason of revising the term was to enable the respondents to answer the questionnaire items based on the technological tools available for use in science teachers' classrooms. The questionnaire contained 30 TPACK items and consisted of four components: 1) 5 items for CK; 2) 9 items for PCKCx; 3) 4 items for TK; and 4) 12 items for TPCKCx. The ratings of the items ranged from 1 (not at all true) to 5 (very true).

The questionnaire was sent to secondary schools (middle and high schools) randomly selected across Taiwan. Since the study was conducted in a different context (i.e., secondary school science teachers), factor analysis was conducted to help the researchers understand whether the change of context influenced the questionnaire items extracted for each factor. In other words, the same questionnaire was used in a different context to verify whether the data collected by the questionnaire could fit the TPACK model developed by Jang and Tsai (2012).

Data collection and participants

The study used a previously developed questionnaire to examine in-service secondary school science teachers' TPACK. The TPACK questionnaire was mailed to secondary schools randomly selected across different parts (i.e., North, Middle, South, East, and Outlying islands) of Taiwan, and return envelopes were provided for completed questionnaires. We numbered the secondary schools in Taiwan and employed simple random sampling to select the participating schools. As participating in the study was voluntary for science teachers, the numbers of the complete questionnaires varied, ranging from 5 to 26. There were 1358 questionnaires returned in total. After deleting the questionnaires with missing data on ratings of TPACK items, there were 1292 questionnaires remained from 123 secondary schools for factor analysis.

After further questionnaires with incomplete basic personal information were excluded (i.e., gender and science teaching experience), 1210 questionnaires remained. Among the 1210 participants, 65 (5.4%) science teachers reported no use of computer technology and 1145 (94.6%) reported use of computer technology. We used the data of the 1145 science teachers from 123 secondary schools for further statistical analyses of teachers' TPACK according to gender and teaching experience.

Data analysis

Factor analysis was conducted with the results of the questionnaire from the remaining 1292 science teachers, to verify whether the TPACK model developed by Jang & Tsai (2012) fits in the context of the study (i.e., with secondary school science teachers). An independent samples *t*-test was conducted when there were two groups (i.e., gender) to be compared for TPACK. ANOVA was conducted when there were more than two groups (i.e., science teaching experience) compared for TPACK.

Results

Factor analysis for the questionnaire within the secondary school context

The rotated Principle Component Analysis indicated that the item TK2 (item No. 16) was categorized in the component TPCKCx, as the value rotated in TPCKCx was .72, while the value rotated in TK was .445 (see Table 1). We further examined the value of corrected item-total correlation and found that when the item TK2 was excluded, the value on the Cronbach's α of the component TK was decreased from .893 to .874. Therefore, we decided to keep the item TK2 within the component TK.

The value of Kaiser-Meyer-Olkin (KMO) was .972. The Bartlett's test of sphericity was significantly different. The Cronbach's α of the overall questionnaire was .959. The Cronbach's α for CK was .904; for PCKCx it was .922; for TK it was .893; and for TPCKCx it was .978. The Pearson's correlation coefficients of the items were all significant, and all items indicated a value over .4. The analyses all fit the requirements of factor analysis.

Table 1
The factor structure of TPACK instrument

	Factor Component			
Item No.	TPCKCx	PCKCx	TK	CK
24	.909			
25	.898			
21	.900			
26	.892			
29	.882			
27	.896			
20	.889			
30	.886			
22	.898			
23	.884			
28	.793			
19	.776			
9		.812		
11		.792		
8		.810		
10		.768		
7		.765		
12		.725		
6		.667		
13		.657		
14		.626		
18			.770	
15			.722	
17			.699	
16			.445	
4				.560
2				.828
1				.762
3				.741
5				.675

Secondary school science teachers' TPACK

Secondary science teachers' TPACK was examined by a developed TPACK questionnaire. The descriptive statistics for secondary school science teachers' TPACK are provided in Table 2. Science teachers rated their TPACK all above average point 3. As viewing the means of the four sub-components, the science teachers rated their TK and TPCKCx lower than CK and PCKCx.

Table 2
Summary of descriptive statistics for secondary school science teachers' TPACK

Components	Number of items	*M*	*SD*
CK	5	4.47	.48
PCKCx	9	4.17	.49
TK	4	3.86	.74
TPCKCx	12	3.65	.79
TPACK	30	4.04	.49

Secondary science teachers' TPACK by gender and teaching experience

Science teachers indicated statistical significance in overall TPACK according to gender (see Table 3). With the consideration of other TPACK sub-components, male science teachers rated their TK significantly higher than did female teachers.

Table 3
Means, standard deviation, and t-test on TPACK by gender

Components /Group	Male (n = 668)		Female (n = 477)		
	M	*SD*	*M*	*SD*	*t*
CK	4.49	.50	4.44	.46	1.791
PCKCx	4.18	.52	4.16	.45	.586
TK	3.97	.75	3.71	.69	6.019***
TPCKCx	3.67	.80	3.62	.76	.987
TPACK	4.08	.51	3.99	.45	3.255**

Note. **$p < .01$, ***$p < .001$.

Secondary school science teachers indicated statistical significance in overall TPACK according to teaching experience in science (see Table 4). As to examine each single sub-component, experienced science teachers tended to rate their CK and PCKCx significantly higher than did novice science teachers. However, teachers with less teaching experience tended to rate their TK and TPCKCx significantly higher than did teachers with more teaching experience in science.

Table 4
Means, standard deviation, and ANOVA on TPACK by teaching experience of year

Components/Group	<5 (n = 205)		6-15 (n = 542)		16-25 (n = 309)		>26 (n = 89)		
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*
CK	4.32	.46	4.47	.48	4.55	.49	4.53	.47	10.714***
PCKCx	4.01	.47	4.17	.49	4.25	.49	4.32	.45	12.911***
TK	3.92	.69	3.95	.68	3.78	.80	3.47	.84	13.061***
TPCKCx	3.66	.73	3.70	.75	3.63	.80	3.38	.99	4.480**
TPACK	3.98	.46	4.08	.47	4.05	.51	3.93	.55	3.890**

Note. **$p < .01$, ***$p < .001$.

Discussion and implications

This study is extended from an empirical study conducted to develop a contextualized TPACK model (Jang & Tsai, 2012). The TPACK model was verified in a different context with in-service secondary school science teachers, and the factorial analytical results confirmed the TPACK model by extracting four TPACK sub-components (i.e., CK, PCKCx, TK, TPCKCx), which are the same as the components in the study of elementary school mathematics and science teachers. The results indicate that the new contextualized TPACK model could be applied to the context of elementary school (i.e., with science and mathematics teachers) and secondary school (i.e., with science teachers) in Taiwan.

The percentage of the report on use or no use of computer technology indicated that a majority of secondary school science teachers (94.6%) in Taiwan used computer technology in their science teaching. Although secondary school science teachers perceived their CK, PCKCx, TK and TPCKCx all above the average of three, they rated their TK and TPCKCx lower than CK and PCKCx. The interpretation of the finding could be that secondary school science teachers were more confident in their content and pedagogical knowledge but were less confident in their technological knowledge itself as well as its relation to content and pedagogical knowledge. Therefore, secondary school science teachers still have potential to develop the skills to effectively integrate technology with content and/or pedagogy knowledge in science teaching.

Secondary school science teachers' overall TPACK indicated significant differences according to gender. We further examined each single TPACK component according to gender and found that male teachers rated the TK questionnaire items significantly higher than did female teachers. Gender differences for variables related to technology have been found by other research studies. Research on gender difference for the use of technology suggests that male and female faculty members' use of technology differ (Spotts, Bowman, & Mertz, 1997). Vekiri and Chronaki (2008) found that as early as the ages of elementary school, students have shown gender differences in technology use, with boys using computers more frequently outside of school and showing more positive computer self-efficacy and value beliefs than girls did. Yuen and Ma (2002) examined pre-service teachers' computer acceptance and found that female pre-service teachers' perceptions of the influence of ease of use on intentions to use computers were higher than those of male pre-service teachers, whereas male pre-service teachers' perceptions of the influence of ease of use on perceived usefulness were higher than those of female pre-service teachers. The findings of these empirical studies are consistent with the findings of the study that gender differences exist in technological knowledge. However, how male and female science teachers differ in their technological knowledge is unknown through the current research approach employed in the study, and further research with qualitative approaches is needed to better understand the differences.

As for teaching experience, experienced teachers rated their CK and PCKCx significantly higher than did novice teachers, whereas novice teachers rated their TK and TPCKCx significantly higher than did experienced teachers. Research on PCK suggests that experienced teachers generally show higher content and pedagogical knowledge as the more years they teach, the more content and pedagogical knowledge could be developed by their actual teaching experience. Friedrichsen et al. (2009), and van Driel, Verloop, and de Vos (1998) stated that experienced teachers' knowledge of integrating content and pedagogy tends to be better as they have more opportunities to accumulate this knowledge through their actual teaching experiences than novice teachers who are still developing their integrative skills and knowledge. The findings of the TPACK sub-components related to technological knowledge were interesting in that teachers with less teaching experience rated this particular type of knowledge higher than did the teachers with more teaching experience. A possible interpretation for this finding is that novice teachers typically are young teachers who have just begun their teaching career and tend to be more willing to take time to learn about technology and integrate it into their teaching, whereas most experienced teachers tend to be older teachers who may have been teaching with traditional teaching strategies for years and may not make efforts to develop new teaching skills and knowledge of integrating technology into teaching. However, from the current study, we could not make clear conclusions about what the differences are and the reasons behind the differences. Therefore, further studies need to be conducted to examine how experienced and novice teachers differ for CK, PCKCx, TK, and TPCKCx.

Based on the findings of the study, we have determined four areas that could have implications for future studies and for policy makers. One implication is that future researchers could consider the new contextualized TPACK model in different contexts as this new model may help better explain the challenge for discriminating the overlapped TPACK sub-components by loading PK and PCK into PCKCx and loading TPK, TCK and TPCK into TPCKCx. As for policy makers, there are three aspects to consider: (1) although most science teachers used computer technology in science teaching, training to develop their integrated skills with computer technology use into practice to increase teaching effectiveness is still needed; (2) training and resources related to computer technology may need to be provided for female science teachers so that their technology related knowledge can be promoted; and (3) training and resources related to computer technology may need to be provided for experienced science teachers so that their technology related knowledge can be enhanced.

Conclusion

The study contributes to the research on TPACK by examining TPACK of in-service secondary school science teachers in Taiwan. The TPACK model was verified by conducting the study in a different context with secondary school science teachers, and the factorial analyses confirmed the four sub-components within the TPACK model, which take contextualized knowledge into consideration. We recommend professional development or teacher preparation programs to employ the TPACK model in various contexts for developing teachers' TPACK. In addition, researchers in the future could use the developed questionnaire to examine teachers' TPACK in different research contexts or with participants of different backgrounds, as results might vary depending on the context and background of participants.

This study also makes contributions to our understanding of differences in science to teachers' TPACK, particularly as this relates to gender and teaching experience. As few existing empirical studies have addressed what these differences are, further research is needed to address the questions.

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