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Exploring the Profiles and Interplays of Pre-service and In-service Teachers' Technological Pedagogical Content Knowledge (TPACK) in China

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ABSTRACT

This research surveyed three hundred and ninety pre-service and three hundred and ninety four in-service teachers with regards to the seven factors of technological pedagogical content knowledge, their beliefs about constructivist oriented teaching (CB) and design disposition (DD). Both exploratory and confirmatory factor analyses showed that the survey based on the nine-factor model had high reliability and validity. Significant differences between pre-service and in-service teachers in the TPACK factors and CB and DD were found and the differences reveal that the pre-service teachers are less knowledgeable and confident with regards to all the factors. In order to identify predictors of TPACK, the research further explores the relationships among TPACK factors, CB and DD through structural equation models. The findings reveal that DD consistently predict both pre-service and in-service teachers' TPACK and this provide support about the importance of design disposition for TPACK advancement. However, CB does not predict the pre-service teachers' TPACK. In addition, CB is a significantly negative predictor for the in-service teachers' TPACK. The findings may imply that while the in-service teachers believe strongly in constructivist oriented teaching, they need further professional development in designing instruction to actualize their desired form of education.

Keyword

Technological pedagogical content knowledge (TPACK), Teachers' beliefs, Design disposition, Teacher education

Introduction

The theoretical framework of technological pedagogical content knowledge (TPACK) has emerged as a widely accepted framework to provide explanation of teachers' work in integrating Information and Communication Technologies (ICT) into classroom (Mishra & Koehler, 2006; Cox & Graham, 2009). The TPACK framework accounts for the integration of ICT from a knowledge perspective. It identifies three elementary forms of knowledge that must be present in any ICT integrated lesson: technological knowledge (TK), pedagogical knowledge (PK) and content knowledge (CK).

The interactions of these three forms of knowledge were postulated to develop other secondary forms of knowledge that include pedagogical content knowledge (PCK) (Shulman, 1986), technological pedagogical knowledge (TPK), technological content knowledge (TCK) and ultimately the synthesized form of knowledge, which is the TPACK. Shulman (1986) postulated that PCK is the unique form of teacher knowledge that synthesizes the teacher's PK and CK to help students in bridging the difficulties of mastering the subject matter. It could be in the form content-specific or topic-specific pedagogical approaches (Graham, Borup, & Smith, 2012). In similar vein, TPK is the unique form of PK that is associated with the use of specific kinds of technology. TCK refers to technologically represented content knowledge that is not created for the purpose of teaching. Finally, TPACK refers to the integrated form of knowledge that can be created through different combination of the six forms of knowledge discuss earlier (Cox et al., 2009). This form of knowledge is created through teachers or educational technologists' design effort when they generate new practices to integrate ICT into classroom teaching (Tsai, Chai, Wong, Hong, & Tan, 2013). Currently, the notion of TPACK is spreading and being adopted by many countries to understand and enhance teachers' ability to integrate ICT (Chai, Koh & Tsai, 2013a).

Researchers in China have also begun to explore teachers' ability to integrate ICT using the TPACK framework. However, the rigor of research may need enhancement (see Zhan & Ren, 2011). In particular, factor analyses were not performed to verify the survey's factor structure. This research aims to explore the Chinese teachers' TPACK profiles and the relationships among TPACK factors, teachers' constructivist beliefs and design disposition through structural equation models.

Theoretical background

Given the growing interest in TPACK, a number of studies that aimed to develop a valid and reliable instrument has emerged (Archambault & Crippen; 2009; Chai, Ng, Lee, Hong, & Koh, 2013b). Methodologically, it seems that Chai and his colleagues' survey instrument possesses good construct validity as revealed through confirmatory and the instrument possesses strong reliabilities. In addition, it fits that Asian context best (see Chai et al., 2013b) and it is based on current emphasis towards constructivist-oriented use of technology in the classrooms.

Theoretically, the elementary forms of knowledge (CK, PK, and TK) and the secondary forms of knowledge (TPK, PCK, and TCK) should act as epistemic resources to support the teachers' development of TPACK. Past research on structural equation models had provided general support that the elementary forms of knowledge are predictors of teachers' TPACK (see Chai et al., 2013b; Kramarski hai, Koh, Tsai, & Tan, 2011). TPACK is thus a situated and complex form of knowledge creation (Mishra & Koehler, 2006; Tee & Lee, 2011) in that the teacher has to consider the students' readiness, prior knowledge, school technological environments, appropriate teaching methods for the topic to be taught and possible technologies with their specific educational affordances; before the teacher can synthesize these elements into a coherent whole for a specific lesson. However, depending on the design experiences, the level of teacher's knowledge and the professional development that teachers received, the elementary or secondary forms of knowledge may or may not contribute to the final TPACK. Further reviews about how the elementary factors of knowledge contribute to higher forms of knowledge are discussed in the next paragraphs.

To date, there are only a couple of studies that could map out the relationships between the seven factors through structural equation model (SEM) (see Koh, Chai & Tsai, 2013; Chai et al., 2013b). The relationships are that each of the elementary factors of TPACK constructs may predict the higher forms of TPACK constructs as proposed by Mishra and Koehler (2006). Koh et al. (2013) reported that among the Singaporean in-service teachers, CK and PCK did not positively predict the teachers' TPACK while the rest of the factors positively predict TPACK. Chai et al.'s (2013b) investigation on Asian pre-service teachers (including Singapore, Hong Kong, Taiwan and Mainland China), however, shows that the direct positive predictors of pre-service teachers' TPACK were TCK, PCK and TPK, with the elementary TK, CK, and PK having only indirect effects. In sum, the SEMs between the pre-service and in-service teachers may not be the same, which implies that teacher educators need to understand the different efficacies of these two groups of teachers to specifically address their TPACK development needs.

Current studies that aimed at understand teachers' TPACK and its elementary form of knowledge through quantitative survey either focused on pre-service teachers or in-service teachers. To understand how teachers' TPACK differ from pre-service to in-service stages necessitate some forms of tracking using similar instrument. Greenhow, Dexter and Hughes (2008) attempted to understand the differences between in-service (n = 17) and pre-service (n = 16) science teachers' performances and instructional decisions for ICT integration base on multimedia case scenarios. More studies are desirable to establish a more generalizable pattern of teachers' TPACK development to compare their difference.

In addition, the adequacy of the TPACK framework has been challenged recently by Voogt and Roblin (2012) and Chai et al. (2013a) in their review of TPACK research. These researchers pointed out that teachers' work has always been shaped by many different strands of beliefs that they hold. The TPACK framework has been thus far focused exclusively on accounting for the knowledge that teachers need to integrate technology. It is therefore necessary to further unpack the relationship between teachers' TPACK and associated beliefs. There are currently few studies that explicitly examine both teachers' TPACK and beliefs concurrently with exceptions such as a correlation study conducted by Chai, Chin, Koh, and Tan (2013c).

Among the related beliefs, we focus on teachers' constructivist beliefs since the integration of ICT is often targeted on students' center knowledge construction (Jonassen & Ionas, 2008). Constructivist beliefs are also known as

"progressive beliefs" or "student-centred approaches" (Bramald et al., 1995) and are often regarded as beliefs that "support student learning" (Samuelowicz & Bain, 1992) and provide a "constructivist philosophy of learning" (Bramald et al., 1995). Those teachers who focus on constructive and progressive teaching and learning processes adopt constructivist beliefs (Sang, Valcke, van Braak, & Tondeur, 2009). As Tondeur and his colleagues (2008) argue, teachers who are more inclined towards adopting constructivist beliefs are more active ICT users compared with teachers who are less inclined towards adopting the constructivist beliefs.

Furthermore, as TPACK is in essence designed knowledge (Chai et al., 2013a), we argue that teachers' disposition towards design is an important aspect of teachers' beliefs that need attention. Design disposition is constituted through the expectations and inclinations of the designer that could influence the design activity (Boland & Collopy, 2004). Expert designers have been found to possess distinctive dimensions of design disposition. These dimensions are the capacity to embrace ambiguity and openness; develop emphatic understanding of user's needs; attend to multidimensional meanings; generating polysensorial aesthetics and creating artefacts and solutions to address the design problems (Michlewski, 2008). Cross (2007) highlighted tolerance towards uncertainty and conflicting ideas and patience towards the emergence of solutions as essential dispositions of designers. In sum, researchers who have studied designers' disposition have identified some intra-personal psychological traits needed for good designers. Traditionally, there may be a higher proportion of teachers who practice teaching as delivery of information rather than designing the learning environment and activities to facilitate students' knowledge construction. However, rapid technological changes challenge the stasis in curriculum and instructional design. In fact, the lack of design capacity has been dubbed as the third order barrier to ICT integration (Tsai & Chai, 2012); following after the first order barrier of access to technology and the second order of teachers' beliefs. We thus propose in this study to investigate the hypothesis that teachers' with stronger design disposition would be more inclined to develop TPACK.

Based on the forgoing review, we hypothesize that the elementary and secondary forms of knowledge would predict TPACK and that the teachers' constructivist beliefs and design disposition would positively predict their TPACK. Figure 1 below depicts the theoretical model formed. The hypotheses (H) tested in this model include:

H1 CK predicts TCK; H2 CK predicts PCK; H3 CK predicts TPACK; H4 TK predicts TPK; H5 TK predicts TCK; H6 TK predicts TPACK; H7 PK predicts TPK; H8 PK predicts PCK; H9 PK predicts TPACK; H10 TCK predicts TPACK; H11 TPK predicts TPACK; H12 PCK predicts TPACK; H13 CB predicts TPACK; H14 DD predicts TPACK.

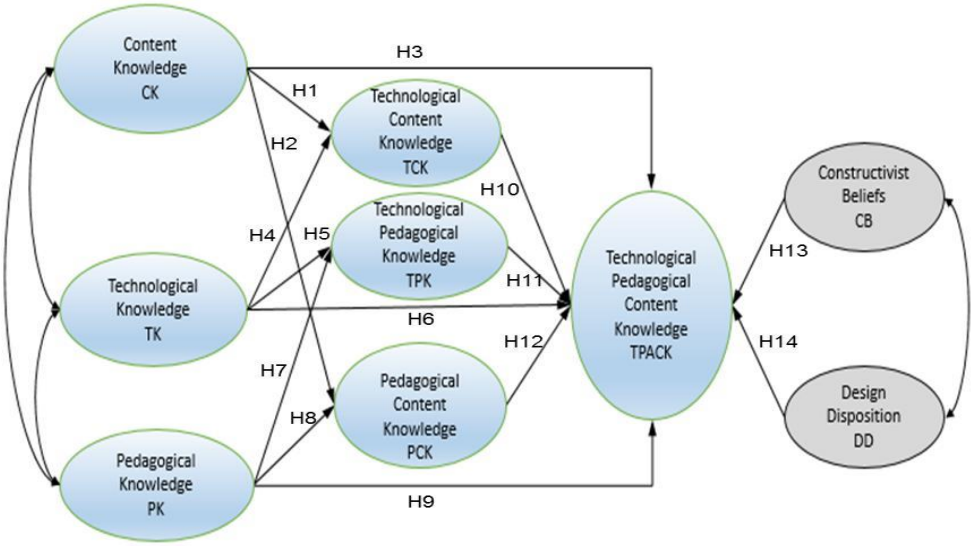

Figure 1. Theoretical model proposed in this paper

Research questions

Based on the reviewed literature, our study aims to address the following research questions:

- Do the nine-factor model that includes the seven TPACK constructs, teachers' constructivist beliefs (CB) and design disposition (DD) fit the Chinese teacher context?
- Are there any differences between pre-service and in-service teachers' TPACK and teachers associated CB and DD?
- Do Chinese pre-service and in-service teachers' TPACK primitive constructs (i.e., TK, PK, CK, TCK, TPK, PCK), CB and DD predict their TPACK?

For research question 1, it was hypothesized that the contextualization of the TPACK survey for Chinese pre-service and in-service teachers would yield satisfactory fit indices for the combined model with the seven TPACK factors as postulated by Mishra & Koehler (2006) and CB and DD proposed in this research. For research question 2, it was hypothesized that Chinese teachers had different TPACK profiles with other contexts and that there were some differences between pre-service and in-service teachers' TPACK. For research question 3, it was hypothesized that CB and DD had both direct contributions to the TPACK as illustrated in Figure 1.

Method

Participants

The participants for our study were 390 pre-service (*M* age = 20.59, *SD* = 1.661) and 394 in-service teachers (*M* age = 36.06, *SD* = 7.226) in Beijing (China). The sample of pre-service teachers in this survey are undergraduates from 11 provinces of China and they will have to go back to their respective province to be primary or secondary school teachers after graduation, according to related policies. Pre-service teachers are majoring six subjects: Chinese Language, English Language, History, Education, Math and Physics.

Table 1. Sample distribution of pre-service and in-service teachers (*N* = 784)

Pre-service	Options	Number (%)	In-service	Options	Number (%)
All sample		390 (100)			394(100)
Gender	Male	131 (33.6)	Gender	Male	81 (20.6)
	Female	259 (66.4)		Female	310(78.7)
Grade	Senior	166 (42.6)	Teaching	< 5 years	57 (14.5)
	Junior	77 (19.7)	Years	6-15 years	160 (40.6)
	Sophomore	89 (22.8)		> 16 years	173 (43.9)
	Freshmen	58 (14.9)			
Family	Rural	206 (52.8)	School	Rural	243 (61.7)
Location	Urban	172 (44.1)	Location	Urban	119 (30.2)

For pre-service teachers (*n* = 390), 259 (66.4%) were female. Most of the respondents were in their last year of college (166, 42.6%). Freshmen were the smallest population of the respondents (58, 14.9%). As to family locations of pre-service teachers, most of them came from rural areas (206, 52.8%), and 172 (44.1%) came from urban areas.

Of all respondents in in-service teachers (*n* = 394), 78.7% teachers were female. Respondents were grouped into 3 categories depending their years of teaching experience: teachers with less than 5 years of teaching experience (14.5%); teachers with 6-15 years of teaching experience (40.6%); and teachers with more than 16 years of teaching experience (43.9%). Furthermore, schools of 243 (61.7%) teachers were located in rural areas, and 119 (30.2%) were located in urban areas.

Instrument

The instrument was adapted from several sources. The TPACK constructs and Constructivism Beliefs were adapted from Chai et al. (2013b) and Chai et al. (2013c) respectively. The 6 items on design deposition were taken from Koh, Chai, Hong and Tsai (2013). A total of 46 items were assembled and they were subsequently translated by two professors majoring in Chinese language. Therefore, the final survey comprised of 46 items that measured teachers' perceptions with respect to the extent to which they agreed or disagreed with statements related to the seven TPACK constructs and their beliefs with respect to the constructivism and design deposition. Each statement was rated as a

seven point Likert-type scale with 1-strongly disagree, 2-disagree, 3-slightly disagree, 4-neutral, 5-slightly agree, 6-agree, 7-strongly agree.

Data collection and analysis

Paper-based surveys were distributed to the participants in the schools for the in-service teachers and during class for the pre-service teachers. The surveys were administered anonymously. The teachers took around 15-20 minutes to complete the surveys. The responses were then collated in SPSS. Since only the TPACK portion survey has been previously validated by Asian pre-service teachers which include China sample, confirmatory factor analysis was performed to ensure that the 9 factors model is valid using AMOS 21. Eight items were deleted including *TPK1, TPK2, TPACK2, PK1, PCK1, PCK2, TCK2, DD2* because these items showed cross loadings or low loadings. Internal reliability was first established through high overall Cronbach's alpha for the survey is 0.98 and the respective Cronbach's alphas are: TK ($\alpha = 0.95$), PK ($\alpha = 0.94$), CK ($\alpha = 0.89$), PCK ($\alpha = 0.95$), TPK ($\alpha = 0.91$), TCK ($\alpha = 0.88$), TPACK ($\alpha = 0.91$), CB ($\alpha = 0.95$), DD ($\alpha = 0.89$). Further analyses based on the model include bivariate correlations, *t*-tests and testing of the structural equation model based on the identified factors.

Results

Measurement model and independent *t*-tests

The CFA performed on the measurement model includes TPACK seven constructs and CB and DD. The CFA obtained satisfactory model fit ($\chi^2 = 2040.63$, $\chi^2/df = 2.91$, $p < 0.001$, TLI = .95, CFI = .96, RMSEA = 0.049 (LO90 = 0.047, HI90 = 0.052), SRMR = 0.071). Table2 shows that nine constructs' mean score, SD, *t* -value between pre-service teachers and in-service teachers. Table 2 also shows that there are significant differences ($p < .001$) between pre-service and in-service teachers in the TPACK constructs and CB and DD. TPACK framework constructs and associated beliefs (CB and DD) of pre-service teachers are lower than those of in-service teachers, especially in the elementary factors (TK, CK, PK). The results also indicate that CK, regardless of pre-service teachers or teachers, is the lowest among CK, TK and PK. CB is higher than others, implying that pre-service and in-service teachers have relatively strong constructivist beliefs.

Table 2. Comparisons between pre-service and in-service teachers' scores

	Type	*N*	Mean	*SD*	*SE*	*t* -Value
TK	Pre-S-T	390	4.48	1.24	.063	-11.00***
	In-S-T	394	5.44	1.20	.060	
CK	Pre-S-T	390	4.01	1.20	.061	-13.99***
	In-S-T	394	5.19	1.16	.058	
PK	Pre-S-T	390	4.60	1.09	.056	-14.07***
	In-S-T	394	5.63	0.97	.049	
PCK	Pre-S-T	390	4.57	1.10	.056	-7.77***
	In-S-T	394	5.20	1.18	.059	
TPK	Pre-S-T	390	4.71	1.10	.055	-6.16***
	In-S-T	394	5.23	1.30	.065	
TCK	Pre-S-T	390	4.43	1.09	.055	-9.61***
	In-S-T	394	5.24	1.26	.063	
TPACK	Pre-S-T	390	4.41	1.07	.054	-7.39***
	In-S-T	394	5.03	1.28	.064	
CB	Pre-S-T	390	5.50	1.25	.063	-7.38***
	In-S-T	394	6.11	1.05	.053	
DD	Pre-S-T	390	4.61	0.96	.048	-9.82***
	In-S-T	394	5.30	1.02	.051	

Note. *** $p < 0.001$.

Correlation analysis

Significant positive correlations between the TPACK constructs were established at $p < 0.01$ (See Table 3), indicating that these relationships could be further examined with SEM. TCK and TPK had the largest positive correlations with TPACK while PCK had relatively lower but positive significant correlation with TPACK. The correlation between CB and TPACK was lower than that between DD and TPACK, which was around 0.60. Similarly, the correlations between CB and other constructs were lower than the correlations between DD and those constructs.

Table 3. Inter-correlations between TPACK constructs and CB, DD

		{1}CK	{2}PK	{3}TK	{4}PCK	{5}TPK	{6}TCK	{7}TPACK	{8}CB
{1}CK	Pre-service								
	In-service								
{2}PK	Pre-service	.69**							
	In-service	.59**							
{3}TK	Pre-service	.55**	.58**						
	In-service	.46**	.49**						
{4}PCK	Pre-service	.58**	.57**	.50**					
	In-service	.49**	.62**	.48**					
{5}TPK	Pre-service	.51**	.55**	.69**	.48**				
	In-service	.40**	.56**	.64**	.55**				
{6}TCK	Pre-service	.50**	.51**	.72**	.45**	.68**			
	In-service	.45**	.52**	.70**	.45**	.64**			
{7}TPACK	Pre-service	.51**	.56**	.71**	.52**	.77**	.79**		
	In-service	.52**	.59**	.69**	.50**	.71**	.75**		
{8}CB	Pre-service	.47**	.61**	.51**	.44**	.40**	.39**	.39**	
	In-service	.15**	.42**	.34**	.43**	.56**	.39**	.42**	
{9}DD	Pre-service	.56**	.57**	.61**	.53**	.62**	.59**	.68**	.44**
	In-service	.45**	.54**	.50**	.50**	.57**	.51**	.58**	.46**

Note. $N_{\text{Pre-service}} = 390$, $N_{\text{In-service}} = 394$. ** $p < 0.01$.

Structural equation model

The results of the structural model based on the hypotheses (displayed in Figure 1) are presented in Figure 2 for pre-service teachers and Figure 3 for in-service teachers. The SEM yielded satisfactory model fit shown in Table 4. The path coefficients are summarized in Table 5 for pre-service and Table 6 for in-service teachers. In the figures, straight line indicates a significant relationship studied in the literature; dashed line indicates a suggested but empirically insignificant relationship in this study.

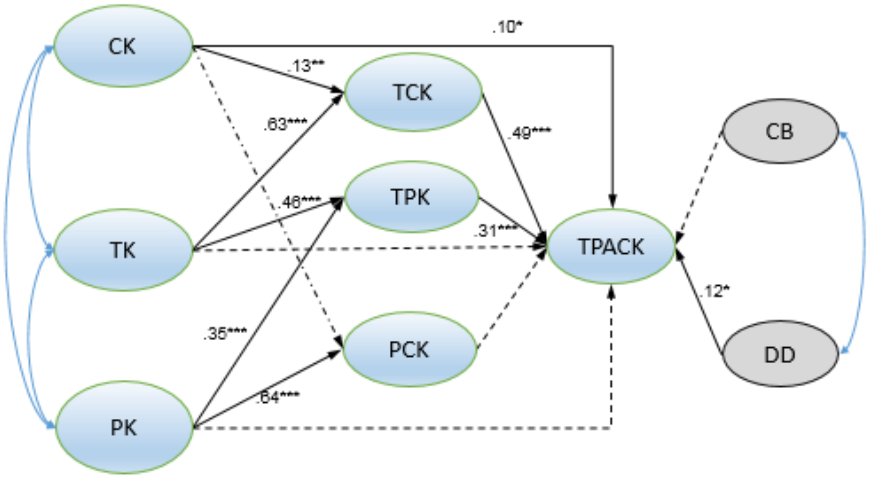

Figure 2. CB, DD and Pre-service Teachers' TPACK

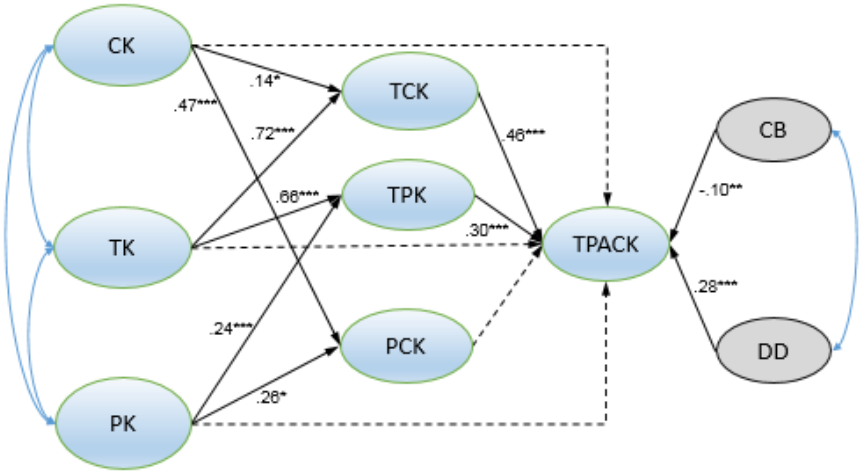

Figure 3. CB, DD and In-service Teachers' TPACK

From Figure 2 and Figure 3, it can be seen that, by and large, most pathways to TPACK as proposed were supported.

Table 4. Model fit summary of pre-service and in-service teachers

Model	χ^2	Df	χ^2/df	IFI	TLI	CFI	RMSEA
Pre-service Teachers	1586.00	712	2.23	.93	.92	.93	.056
In-service Teachers	1845.99	712	2.59	.93	.92	.93	.063

Table 5. Path coefficients of the TPACK SEM (for pre-service teachers)

Hypotheses	Path			Estimate	*SE*	C.R.	*p* values	Supported ?
H1	CK	→	TCK	.13	.04	3.28	**	Yes
H2	CK	→	PCK	.09	.05	1.70		No
H7	PK	→	TPK	.35	.05	6.36	***	Yes
H8	PK	→	PCK	.64	.07	8.65	***	Yes
H5	TK	→	TPK	.46	.05	9.98	***	Yes
H4	TK	→	TCK	.63	.05	12.55	***	Yes
H3	CK	→	TPACK	.10	.04	2.31	*	Yes
H9	PK	→	TPACK	.05	.07	.72		No
H6	TK	→	TPACK	-.00	.07	-.02		No
H11	TPK	→	TPACK	.31	.06	5.26	***	Yes
H10	TCK	→	TPACK	.49	.07	7.05	***	Yes
H12	PCK	→	TPACK	-.05	.04	-1.21		No
H13	CB	→	TPACK	-.01	.03	-.25		No
H14	DD	→	TPACK	.12	.06	2.14	*	Yes

Note. $^{***}p < 0.001$. $^{**}p < 0.01$. $^{*}p < 0.05$.

Table 6. Path coefficients of the TPACK SEM (for in-service teachers)

Hypotheses	Path			Estimate	*SE*	C.R.	*p* values	Supported ?
H1	CK	→	TCK	.18	.06	2.47	**	Yes
H2	CK	→	PCK	.47	.10	4.86	***	Yes
H7	PK	→	TPK	.24	.07	3.49	***	Yes
H8	PK	→	PCK	.26	.11	2.35	*	Yes
H5	TK	→	TPK	.66	.05	12.63	***	Yes
H4	TK	→	TCK	.72	.06	12.78	***	Yes
H3	CK	→	TPACK	-.12	.07	-1. 80		No
H9	PK	→	TPACK	.07	.08	.87		No
H6	TK	→	TPACK	-.03	.07	-.42		No

H11	TPK	→	TPACK	.30	.04	7.00	***	Yes
H10	TCK	→	TPACK	.46	.06	7.96	***	Yes
H12	PCK	→	TPACK	.07	.08	1.91		No
H13	CB	→	TPACK	-.10	.04	-2.70	**	Yes, but negatively
H14	DD	→	TPACK	.28	.05	5.21	***	Yes

Note. $^{***}p < 0.001$. $^{**}p < 0.01$. $^{*}p < 0.05$.

Figure 2 depicts the path coefficients that significantly predict TPACK constructs of pre-service teachers. The results indicated that teachers perceived three direct paths to TPACK from CK, TCK and TPK. They also perceived DD as predictor of their TPACK (See Figure 2). However, TCK and TPK had larger path coefficients, indicating that these were perceived to have stronger prediction on TPACK than CK and DD. Among these four predictors, TCK had the largest path coefficient. The results indicated that TK and PK were perceived to predict teachers' PCK. However, no significant path between PCK and TPACK was established, indicating that the teachers did not perceive significant relationships between their PCK and TPACK. The direct pathways of CK on PCK and CB on TPACK were also not significant.

Figure 3 depicts the path coefficients of significant paths towards TPACK constructs of in-service teachers. The study results indicated that teachers perceived four direct paths to TPACK from TCK and TPK. They perceived both CB and DD to be predictors of their TPACK (See Figure3). However, TCK and TPK had larger path coefficients, indicating that these were perceived to be stronger predictors of TPACK than CB and DD. Among these four direct paths, TCK had the largest path coefficient. The study results indicated that TK and PK were perceived to be predictors of teachers' PCK. However, no significant path between PCK and TPACK was established, indicating that the in-service teachers did not perceive significant relationships between their PCK and TPACK.

Discussion

This study indicates that the nine factors survey we adapted to measure the Chinese pre-service and in-service teachers' TPACK and associated beliefs possesses construct validity as assessed through CFA. The reliabilities were also strong. This finding advances research of TPACK in that it has provided a possible instrument to measure teachers' beliefs (CB and DD) and their TPACK concurrently. The validation of the 9 factors TPACK and CB and DD survey helps researchers in unpacking the complex relationships among these constructs. This research therefore is based on Chai et al.'s (2011, 2013b, 2013c) research by an expanded model of teachers' TPACK that considers not only the 7 factors of knowledge but it also included important beliefs associated with TPACK. In addition, the additional beliefs were examined through SEM to investigate whether or not they are significant predictors (see later). In particular, Chai et al. (2013c) began the work of investigating teachers' beliefs with TPACK through correlations and it is conducted specifically for Singaporean Chinese language teacher. It is therefore a subject specific study. This study involves a larger sample of both in-service and pre-service teachers from China and the teachers specialized in different subject matter teaching.

Table 2 provides the mean scores and standard deviations for each factor measured with two groups. Pre-service teachers' TPACK constructs and associated beliefs were all lower than in-service teachers. In terms of the pre-service teachers' TPACK profile, it shows that the teachers perceived themselves strongest in term of their TPK (M = 4.71, SD = 1.09) and weakest in terms of their CK (M = 4.01, SD = 1.20). All other factors of TPACK fall within these range, indicating that the pre-service teachers do not possess high efficacy about TPACK knowledge. It seems necessary for educational institutions in China to review the related technology courses and engage pre-service teachers to integrate ICT through design. Adaptations of reported pre-service teacher curriculum targeting at enhancing pre-service teachers ICT integration could be helpful (see Angeli & Valanides, 2013; Chai et al., 2011; Zhan et al., 2011). The method of technology mapping could improve the pre-service teachers' design capacities.

In terms of the in-service teachers' TPACK profile, it shows that the teachers perceived themselves strongest in term of their PK (M = 5.63, SD = .97) and weakest in terms of their TPACK (M = 5.03, SD = 1.28). The profile we obtained through the survey indicated that Chinese in-service teachers are at least with some confidence in their TPACK but it also reveals that there is a clear need to further develop the teachers' TPACK, especially through professional development activities that directly engage them in designing ICT integrated lesson (Mishra & Koehler,

2006). Engaging in-service teachers to work in groups to design instruction collaboratively could provide the necessary means to improve their TPACK (see Koehler, Mishra & Yahya, 2007).

With regards to the beliefs measured, both the pre-service and the in-service teachers are inclined toward constructivist beliefs, with the in-service teachers expressing stronger inclinations toward CB. These findings are similar to Sang and his colleagues' studies in Chinese educational settings (e.g., Sang et al., 2009; Sang, Valcke, Tondeur, van Braak, & Zhu, 2012). As for their DD, both groups does not seem to be adverse about design problems but their comfort level may need to be enhanced as integrating ICT into classroom is in essence dealing with the wicked problems associated with design (Chai et al., 2011). It may be beneficial to explicitly point out to the teachers that the epistemic nature of creating ICT integration lesson is knowledge creation in a designedly ways of knowing (Chai et al., 2011; Tee et al., 2011); and such endeavor involves dealing with multiple possible solutions without clear criteria about which solution is superior. The assessment about the quality of the designed solution is a situated form of knowledge critique that has to be socially constructed. When one is conscious that one is engaged in knowledge creation work, one may better appreciate the uncertainty involves and adjust one's expectation accordingly. Further research on how teacher's consciousness about the epistemic nature of creating TPACK influence their design cognition; in comparison with those teachers who are not conscious about it; would deepen our understanding about TPACK creation.

The differences between the pre-service and in-service teachers for all factors measured were found to be significant (all $p < 0.001$). This study may be the first in TPACK research to provide quantitative comparison of pre-service versus in-service teachers' TPACK and associated beliefs. The study attests to the importance of practice in shaping teachers' knowledge efficacy, as researchers had claimed (e.g., Darling-Hammond, 2006; Zeichner, 2010). While the pre-service teachers acquire different forms of knowledge in the teacher education institutes, they could not be sure about the sufficiency of the knowledge or the skills unless they have adequate teaching experiences and practical field knowledge. We believe that this could be the reason that the pre-service teachers' scores hover near mid points. However, we also note that the pre-service teachers are not negative in the assessment of their needed knowledge for ICT integration. As for the in-service teachers, they are more confident in most of the knowledge factors except for TPACK, which has been characterized as complex, situated and essentially designed outcome (Cox et al., 2009; Mishra et al., 2006). This form of knowledge is dynamic and has to be viewed more as knowing rather than knowledge. In addition, it is worth noting that the in-service teachers are having stronger efficacy on TK than the pre-service teachers, which is not quite consistent with the general expectation that younger teachers are stronger with technology (see also Lee and Tsai, 2010). The reason could be that the in-service teachers are from Beijing's districts that are constantly working with universities to improve their ICT integration. In any case, more research through qualitative approach is needed to further unpack the differences.

The hypotheses were depicted in Figure 1 and we predicted based on previous theory and research that the elementary forms of knowledge are knowledge resources that contribute to the teachers TPACK and that CB and DD would contribute teachers' TPACK. We discussed the hypotheses concerning the TPACK factors first before moving into CB and DD. In general, the SEMs obtained support that the elementary forms (CK, PK, TK) predict the secondary forms of knowledge (TPK, TCK, PCK), and TCK and TPK predict TPACK. However, PCK did not predict TPCK for both groups of teachers. For the pre-service teachers, CK did not predict PCK, and TK and PK also did not predict TPACK directly. In addition, PCK did not predict TPACK, but CK directly predict TPACK. The structural equation models that we have obtained bear similarity and differences as compared to what has been published to date. Chai et al. (2013b) obtained similar results among Asian pre-service teachers, which include another sample of Chinese pre-service teachers from another region. However, PCK was a significant predictor of TPACK for Chai et al.'s (2013b) study.

For the in-service teachers, CK predicts PCK and TCK, but did not directly predict TPACK. Similar findings were obtained when it is compared to Singapore in-service teachers except that for Singapore in-service teachers (see Koh et al., 2013). Considering these three studies, it can be seen that elementary TPACK factors (CK, PK, TK) may or may not predict the final factors directly; whereas TPK and TCK consistently predict TPACK (see Koh, Chai & Tsai, 2014). Whether or not PCK positively predict TPACK is dependent on the specific samples. In any case, it seems that teachers did not perceive PCK as a strong positive predictor of TPACK when the path coefficients are taken into account. It seems that more work on helping teachers to link their established PCK with the technology related factors is important. The finding we obtained could signify that once PCK is formed, teachers tend not make conscious effort in building the technology to it.

When the two models are compared, it seems that the in-service teachers have a model that more closely reflects the theoretical model while the pre-service model seems more fragmented. This is a reasonable outcome as the in-service teachers are likely to have more experience in synthesizing TPACK or PCK since designing or adapting lessons is part of teachers' work. This study contributes to TPACK literature in providing the SEM models for tangible comparison to be made.

Finally, this study identifies the CB and DD as other factors that could predict teachers TPACK. The findings we obtained indicate that DD is a positive predictor for both teachers, but CB is only a negative predictor for in-service teachers. The results are consistent with our research hypothesis that teachers' DD can predict their TPACK's development, but it did not support the hypothesis of CB predicting TPACK. The case for DD provides some support to the argument that teacher's design capacity could be a barrier to ICT integration (Tsai & Chai, 2012). Furthermore, the findings provide support for teacher educators to consider ways of enhancing the teachers' design position. Explicit discussion about how teachers should handle classroom situations that call for design and scaffolding teachers with general heuristics or cognitive prompts could be helpful (see Kramarski & Michalsky, 2010).

For the unexpected finding of CB being a significant negative predictor of TPACK for the China in-service teachers from Beijing, further discussion is needed. The findings we obtained indicate that the teachers possess high level of constructivist beliefs but the beliefs are significant negative predictors of the teachers' TPACK. This may indicate that while the teachers believe strongly in constructivist teaching, they are conscious that they lack the design capacity to craft constructivist oriented TPACK. The TPACK items we used in this research refer to teachers' ability to use technology for student-centered learning for specific subject matters. Sample items include "I can formulate in-depth discussion topics about the content knowledge and facilitate students' online collaboration with appropriate tools." Pedagogical activities such as these are student-centered and are usually undergirded by constructivist beliefs towards education (Howland, Jonassen, & Marra, 2012). Past research has also documented that teachers with constructivist beliefs are likely to advocate constructivist oriented ICT-based lesson (Chai, 2010; Sang, Valcke, van Braak, & Tondeur, 2010). However, whether or not they perceived themselves as capable in designing such research was less researched. The finding indicates that possessing constructivist beliefs may not be a sufficient condition for teachers' TPACK development. Moreover, if adequate professional development is not provided, the in-service teachers' CB may become a barrier for them to implement some lesson plans that require TPACK. This research has therefore contributed to current literature about teachers' beliefs and their perceived competency. While beliefs and knowledge are usually correlated, they are not the same thing. Beliefs denote more of an ideal situation while knowledge is akin to actual situation. Our findings may indicate a situation where the teachers wish to conduct ICT integrated lesson supported by technology but they are not sure that they are able to design such lesson. Again, there is a clear need for further development of teachers' design capacity.

Overall, the identification of two additional predictors for TPACK imply that developing teachers' TPACK from the perspective of equipping the teachers with relevant knowledge and design experience could be further enhance by attention towards beliefs about themselves as designer (DD) and their teaching beliefs (CB) (see Voogt et al., 2013).

Conclusion, implications, and limitations

This study confirms that the nine-factor model that includes the seven TPACK constructs, teachers' constructivist beliefs and design disposition can be used to explore the Chinese teachers' TPACK profiles and their development. The 9-factor-model instrument has been developed and validated for both the pre-service and in-service teachers. This study indicated that there were significant differences between these teachers' TPACK and that design disposition had positive contribution to the TPACK for all teachers, but constructivist beliefs was only a negative predictor for in-service teachers.

There are several implications for teacher education in China. A better understanding of teacher's beliefs and TPACK can help to improve the efficiency of teacher education programs. An important goal of teacher education programs should consequently be to help teachers developing beliefs that are consistent with the needs of the current or new educational system related to educational technology. In addition, considering the differences between pre-service and in-service teachers, teacher preparation courses should pay much attention to improve student teachers' knowledge and skill and educational technology and ICT integration.

This study results should be considered in light of several methodological limitations. Firstly, considering difficulties of understanding beliefs and knowledge, quantitative method is not the only way of exploring TPACK and teacher beliefs. More research through qualitative approach is needed to further unpack the above differences and to provide rich data for the refined understanding of the situation. The qualitative case study approach proposed by Jimoyiannis (2010) may be adapted for this purpose. Secondly, although teachers' design disposition predicts their TPACK, intervention study is needed to discover causal relationship between them. Thirdly, the results and the model proposed fit only in the Chinese teachers; comparative studies are needed to compare with counterparts in different educational contexts.

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