Validation and profile of Chinese pre-service teachers’ technological pedagogical content knowledge scale

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Researchers state that teachers in different contexts reported different technological pedagogical content knowledge (TPACK). This phenomenon may partially be explained by cultural differences. Based on this consideration, the development and validation of the Chinese pre-service teachers’ technological pedagogical content knowledge (CTPCK) scale is described in this article. The sample was split into two subsamples on random basis ($n_1 = 229$, $n_2 = 207$) for the purpose of conducting (1) exploratory factor analysis (EFA) and (2) confirmatory factor analysis (CFA), respectively. After the EFA, the CTPCK scale excluded six items and included eight factors with 42 items. Reliability and correlations were discussed. The findings revealed that the CTPCK scale was a valid and reliable instrument for measuring the TPACK of Chinese pre-service teachers’ knowledge with or without linking educational technology.

**Keywords:** educational technology; pre-service teacher; teacher education; technological pedagogical content knowledge

1. **Introduction**

In recent decades, researchers stress the potential of employing educational technology in educational contexts to enrich learning environments, foster flexible knowledge construction, cater to individual differences, and improve the quality of education (e.g., Godfrey, 2001; Sang, Valcke, van Braak, Tondeur, & Zhu, 2011). To achieve these educational technology aims, schoolteachers should be prepared to efficiently integrate educational technology into their teaching practices (Pelgrum, 2001).

Teacher education programs all over the world have recognised the challenges associated with developing teachers’ abilities to use technology in the classroom and have proposed original, innovative strategies to enhance student teachers’ competencies to integrate technology (e.g., Angeli & Valanides, 2005). However, the review of Tondeur et al. (2012) suggests that many pre-service teachers continue to feel that they are not well prepared to effectively use technology in their classrooms. The studies included in this review indicate that pre-service teacher education should focus on not only how to use technology but also how technology can be used for teaching and learning. In China, researchers have also indicated that student teachers are not adequately equipped with sufficient technological pedagogical content knowledge (TPACK). TPACK is currently viewed as the most widely accepted framework to account for the knowledge teachers need to integrate educational technology. Chinese student teachers lack TPACK because
they are being offered courses that focus mainly on software knowledge (e.g., the use of Microsoft Office, Flash) that is not linked to specific educational contexts (Zhan & Ren, 2011).

As Kabakci-Yurdakul et al. (2012) suggest, the approaches related to technology integration in education have transformed from techno-centric integration to techno-pedagogical integration. In this respect, TPACK has been a burgeoning research focus, especially among teacher educators and researchers in the field of educational technology (Chai, Koh, & Tsai, 2013). As Chai, Koh, et al. (2013) claim, by understanding the influences of different TPACK constructs or other factors, teacher educators can better support educational technology program design and evaluation. However, these types of studies have not often been conducted because many TPACK surveys are still in the process of construct validation (see Graham et al., 2009; Schmidt, Baran, Thompson, Koehler, & Shin, 2009).

Therefore, this study’s key objective is to develop an instrument to measure pre-service teachers’ TPACK. More specifically, we adapted the TPACK survey reported by Chai, Ng, Lee, Hong, and Koh (2013) and attempted to validate it with both EFA and CFA, exclusively using Chinese pre-service teachers as our sample. Previous researches either use the same sample for both EFA and CFA among Singaporean pre-service teachers (Chai, Koh, & Tsai, 2013) or are limited to CFA among pre-service teachers from various regions in Asia (Chai, Ng, et al., 2013). A rigorously validated instrument for measuring Chinese pre-service teachers’ technological pedagogical content knowledge (CTPCK) is still lacking. Before describing the empirical study, we first define the concept of TPACK. Then, we examine how TPACK has been measured in recent educational research. In this background, we focus on a questionnaire survey measurement of TPACK, considering the methodological base of this article. The article concludes with some practical implications and recommendations for further research.

2. Theoretical background

2.1. Defining TPACK

Already in 2001, the term TPACK was used to define technology integration in the classroom (Keating & Evans et al., 2001; Pierson, 2001). As a framework that describes the professional knowledge of teaching with technology, TPACK was again introduced by Koehler and Mishra (2005). Originally, TPACK was derived from Shulman’s (Shulman, 1986, 1987) well-known work on pedagogical content knowledge (PCK), which has been considered a unique feature of teachers’ professional knowledge – teachers are able to integrate subject knowledge with appropriate pedagogical approaches so that learners are able to understand the subject (Voogt, Fisser, Pareja, Tondeur, & van Braak, 2013). TPACK adds technology-related knowledge (TK) as an indispensable part of teachers’ professional knowledge in the age of information technology (Koehler & Mishra, 2005).

TPACK refers to the synthesised form of knowledge for the purpose of integrating educational technology into classroom practices (Chai, Koh, et al., 2013). Originally given the acronym of TPACK, the acronym has recently been changed to TPACK for the ease of pronunciation (see Thompson & Mishra, 2007). TPACK is a “teacher’s knowledge of how to coordinate subject – or topic-specific activities with topic-specific representations using emerging technologies to facilitate student learning” (Cox & Graham, 2009, p. 64). TPACK has been described as situated, complex, multifaceted, integrative, and/or transformative knowledge (Angeli & Valanides, 2009; Koehler & Mishra, 2009).
Figure 1 shows the diagrammatic depiction of the relations among the seven constructs. This framework has been widely adopted for teacher preparation of educational technology integration and used as a theoretical underpinning for TPACK-related surveys (Cox & Graham, 2009; Thompson & Mishra, 2007; Voogt et al., 2013).

The three main components (constructs) of teacher knowledge in the TPACK framework are content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK). The other components, PCK, technological content knowledge (TCK), technological pedagogical knowledge (TPK), and TPACK, are knowledge developed through the interactions between and among these bodies of knowledge (Koehler & Mishra, 2005, 2009).

2.2. Measuring TPACK

As Voogt et al. (2013) reviewed, the seven components of the TPACK framework can be represented as sub-scales. Efforts to construct surveys for this purpose began with Koehler and Mishra (2005). They constructed a 14-item survey to chart 12 graduate students’ developmental trajectories as these teachers engaged in designing a technology-integrated lesson. Subsequently, Archambault and Crippen (2009) study examined K-12 online distance educators’ knowledge in the United States with respect to each of the TPACK framework components. They found that responding online teachers felt very good about their knowledge related to the domains of pedagogy, content, and pedagogical content, and were less confident when it comes to technology. In the same time, Schmidt et al. (2009) constructed the Survey of Pre-service Teachers’ Knowledge of Teaching and Technology with 124 pre-service teachers in the United States, which consisted of 58
items that measure all seven TPACK constructs, for the content areas of mathematics, social studies, science, and literacy. Recently, based on a survey with pre-service teachers, Sahin (2011) developed an instrument with seven subscales according to the components of TPACK framework. However, the factors were identified through a rather atypical way, using different single factors for analysis. Throughout those studies, Archambault and Crippen’s survey includes three factors, which renders it invalid to assess the seven knowledge factors. The studies of Schmidt et al. and Sahin may lack methodological rigor because the validations were conducted one factor at a time. Brantley-Dias and Ertmer (2013) criticised that the 7-factor solutions were too complex for research and one of the bases for criticism is that the seven factors were usually unidentifiable. Such criticism threaten to put emerging TPACK research into different directions but if it can be showed that the seven factors are identifiable and stable, measurement issues would be resolved.

Researchers have discussed teachers’ knowledge related to Internet/Web technology (Barbera, 2004; Lee & Tsai, 2010; Wallace, 2004). For instance, Lee and Tsai (2010) developed a 30-item TPACK survey focusing on Taiwanese teachers’ self-efficacy for Web-based learning with respect to four TPACK constructs – Web-general and Web-communicative (i.e., two TK factors), Web-content knowledge (i.e., TCK), Web-pedagogical knowledge (i.e., TPK), and Web-pedagogical content knowledge (i.e., TPACK) – and an additional construct of attitudes towards Web-based instruction.

TPACK surveys have also been administered with Asian teachers. Chai and his colleagues, for instance, have carried out a series of surveys to investigate the profiles of Singaporean pre-service teachers in terms of their TPACK (e.g., Chai, Koh, & Tsai, 2010; Chai, Koh, Tsai, & Tan, 2011). To illustrate, the Chai et al. study (Chai, Koh, Tsai, et al., 2011) uncovers five of the seven TPACK constructs, which were a better model fit than several extant TPACK survey studies (e.g., Archambault & Crippen, 2009).

2.3. Construct validation challenges

Several studies reported challenges with TPACK construct validation. Specifically, the seven-component TPACK framework could not be reproduced through EFA (Archambault & Crippen, 2009; Koh, Chai, & Tsai, 2010), indicating that the boundaries between the components are fuzzy (Graham, 2011; also see Voogt et al., 2013). For instance, Archambault and Crippen’s (2009) exploratory factor analysis (EFA) of a TPACK survey for online teaching found that CK, PK, and PCK items loaded as one factor, whereas TPK, TCK, and TPACK items loaded as another. Lee and Tsai (2010) were able to isolate TK, TPK, TCK, and TPACK factors but found that PK and PCK items had loaded as one factor.

Although Chai and his colleagues’ efforts to validate the TPACK instrument are laudable, the only validation that involves both EFA and CFA uses the same participants (see Chai, Koh, Tsai, et al., 2011). These analyses may suffer in terms of research rigor in instrument validation. Chai and colleagues’ subsequent studies reported solely CFA, including a recent study for pre-service teachers in Mainland China, Taiwan, and Singapore (Chai, Ng, et al., 2013). To ensure that the TPACK survey possesses high levels of reliability and validity, this study builds on Chai and his colleagues’ work to validate a Chinese version of the TPACK survey for Chinese pre-service teachers. This survey’s validation would then allow Chinese teacher education institutes to access their pre-service teachers’ TPACK profiles for the planning, implementation, and assessment of pre-service teacher preparation effectiveness in the field of technology integration.
2.4. Purpose of the present study

Considering construct validation challenges in previous studies and TPACK necessities in Chinese contexts, the present study’s purpose is to develop and validate a tool that empirically measures and describes pre-service teachers’ TPACK. To that end, this article contains three distinct phases: (1) item pool development for pre-service teachers’ TPACK and exploration of its factor structure; (2) confirmation and refinement of the received instrument; and (3) exploration of the correlations among different scale factors.

3. Methodology

3.1. Measures

To develop and validate an instrument that measures CTPCK, items were adapted from a TPACK survey in Singapore (Chai, Ng, et al., 2013). In that study, the survey instruments developed by Schmidt et al. (2009) and Koh et al. (2010) were selected to analyse Singaporean teachers’ CK with respect to teaching subject variation. Chai and his colleagues created 13 items to substitute for the PK items in the Schmidt et al. (2009) survey to better address information and communication technology (ICT) courses’ pedagogical emphasis.

The Internet has become one of the most common instructional tools because of recent developments in telecommunications technology (Açıklalı, 2009; Tsai & Tsai, 2003). Accordingly, teachers increasingly support the use of the Internet in their classroom teaching. Considering these trends, technological knowledge about the World Wide Web (TKW) was added to the present study’s instrument development, considering the crucial importance of the Internet for education today. The original English version instrument in Singaporean settings was translated into Chinese by one of the authors and then was rechecked by three scholars in educational sciences. All four participants had excellent bilingual competence in both languages. Table 1 shows definitions and examples of each CTPCK construct.

The final instrument therefore included 42 questions (see Appendix) that were measured on a 7-point Likert scale: (1) Strongly disagree (2) Disagree (3) Disagree somewhat (4) Neither agree nor disagree (5) Agree somewhat (6) Agree (7) Strongly agree.

3.2. Sample

The CTPCK was presented to 445 undergraduate pre-service teachers in a teacher education institute in Beijing (China). A total of 445 respondents, representing a response rate of 100%, completed the questionnaire. A total of nine respondents had more than 10% missing data and were removed from the analysis. As a result, there were 436 pre-service teachers participating in this study.

The sample included 293 (67.2%) female and 143 (32.8%) male respondents. The age of the respondents ranged from 17 to 25 years, with an average of 20.6 years. With regard to participants’ family backgrounds, 232 (53.2%) were from rural regions and 192 (44%) from urban regions. Students’ school years were asked. 179 (41.1%) of respondents were freshmen, 86 (19.7%) were sophomores, 113 (25.9%) were juniors, and 58 (13.3%) were seniors. As for participant majors, seven majors were reported: Chinese language (79, 18.1%), English language (66, 15.1%), history (73, 16.7%), educational technology (64, 14.7%), mathematics (59, 13.5%), physics (81, 18.6%), and psychology (14, 3.2%).
needs illustration is that the reason we conclude students majoring in educational technology in the sample without considering biasing: they had not received any TPACK related instruction in their courses, since TPACK is a newly introduced thing in China and still being explored by researchers. There is only one intervention study on student teachers' TPACK can be found in Chinese settings (Zhan & Ren, 2011).

3.3. Data collection and analysis

To make the observed results most probable, we assessed whether the mean, variance, and coefficients of skewness and kurtosis were normally distributed. According to Kline (2010), skewness coefficients with a range of no more than 3.0 and kurtosis coefficients with a range of no more than 10.0 are considered normally distributed data fits. The analysis \((n = 436)\) of the skewness coefficient was between \(-.673\) and .04, and the kurtosis coefficient was between \(-.573\) and .057, which falls within the recommended range.

To develop and evaluate the CTPCK, we conducted factor analyses. First, EFAs (principal axis factoring) using SPSS were performed on the results of the first stratified random subsample \((n = 229)\) to identify scale clusters in terms of TPACK. Second, to examine the exploratory factor structure’s stability, after removing items with low factor loadings and cross-loadings, confirmatory factor analyses (CFAs) were performed on the second stratified random subsample \((n = 207)\) data, using AMOS 18, following the procedures recommended by Hu and Bentler (1999). Last, the score reliability of the final version of the CTPCK was determined.

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK</td>
<td>Knowledge of the subject matter.</td>
<td>I have sufficient knowledge about my teaching subject.</td>
</tr>
<tr>
<td>PK</td>
<td>Knowledge about the student learning, instructional methods and processes, different educational theories, and learning assessment.</td>
<td>I am able to guide my students to adopt appropriate learning strategies.</td>
</tr>
<tr>
<td>TK</td>
<td>Knowledge about technology features, capacities, and applications.</td>
<td>I have the technical skills to use computers effectively.</td>
</tr>
<tr>
<td>PCK</td>
<td>Knowledge of adopting pedagogical strategies to make the subject matter more understandable for learners.</td>
<td>Without using technology, I can address common learning difficulties that my students have for my teaching subject.</td>
</tr>
<tr>
<td>TPK</td>
<td>Knowledge of the existence and specifications of various technologies to enable teaching approaches.</td>
<td>I am able to facilitate students’ use of technology to find more information on their own.</td>
</tr>
<tr>
<td>TCK</td>
<td>Knowledge about how to use technology to represent the content in different ways.</td>
<td>I know about the available technologies that I can use for the research of content regarding my teaching subject.</td>
</tr>
<tr>
<td>TKW</td>
<td>Knowledge about World Wide Web features, capacities and applications.</td>
<td>I am able to use social media (e.g., Blogs, Wikis, Facebook).</td>
</tr>
<tr>
<td>TPACK</td>
<td>Knowledge of using various technologies to teach and represent the designed subject content.</td>
<td>I can craft real-world problems about the content knowledge and represent them through computers to engage my students.</td>
</tr>
</tbody>
</table>
4. Results

4.1. Exploratory factor analyses

The results of the first stratified random subsample \((n = 229)\) were used to conduct EFAs, which helped identify a number of latent factors in pre-service teachers’ TPACK. To reset the correlations between factors and to help interpret the factors, varimax rotation was used. To interpret the factors, we opted for factor loadings larger than .60. Because the original instrument had many items and we wanted a pure factor measure, we retained strong factor loadings. Considering low factor loadings and cross-loadings (six items), an eight-factor solution was accepted, along with 36 items.

The KMO sample competency was measured to test the sample size validity statistically. The KMO value, which can be between zero and one, is interpreted as normal if it is between .5 and .7, as good if it is between .7 and .8, as very good if it is between .8 and .9 and as excellent if it is greater than .9 (Field, 2005). The resulting KMO value was .958. Because the calculated KMO value was higher than .9, the sample size was considered highly acceptable.

Based on the results presented in Table 2, the eight-factor solution accounted for the 79.12% of the variance (PCK = 45.23, PK = 10.11, TK = 6.49, TPK = 4.52, CK = 3.07, TPACK = 2.87, TCK = 2.43, TKW = 2.23). A variance value above 40% is considered sufficient for social science studies (Gorsuch, 1983; Netemeyer, Bearden, & Sharma, 2003). Therefore, this study’s total variance was perfectly within the acceptable limits.

4.2. Confirmatory factor analyses

Based on the data from the second stratified random subsample \((n = 207)\), CFA was conducted with the AMOS program to determine if these factors efficiently represented the variable groups contributing to the factors in the eight-dimension CTPCK scale resulting from the EFA.

In evaluating the model fit, we supplemented the model chi-square statistic with both absolute and incremental fit indices (Bentler & Bonett, 1980; Hu & Bentler, 1998, 1999). Absolute fit indices evaluate how well an \textit{a priori} model reproduces the sample data. We report a root mean square error of approximation (RMSEA), for which a value less than .06 indicates a good model fit (Hu & Bentler, 1999) and a value less than .08 suggests a reasonable model fit (Browne & Cudeck, 1992). We also report the standardised root mean square residual (SRMR), for which a value of .08 or lower indicates a good fit (Hu & Bentler, 1999). Incremental fit indices evaluate model fit by comparing a target model to a baseline model. Typically, the null model, in which all observed variables are uncorrelated, is used as the baseline model. We report the comparative fit index (CFI) and the Tucker–Lewis index (TLI), which have approximate cut-off values of .95 (Hu & Bentler, 1999). After the examination of parameter estimates, fit indices and residuals, model modifications are conducted on the original hypothesised model to establish a better fitting or more parsimonious model (Schreiber, Nora, Stage, Barlow, & King, 2006).

The confirmative factor analysis results revealed a moderate model fit \((\chi^2 = 995.285 \ [df = 566, \ p < .001])\). The goodness-of-fit estimates were CFI = .923 and TLI = .915, SRMR = .051, RMSEA = .061 with a 90% interval of .054 to .067, indicating that the eight-factor solution represents a reasonably good approximation.

4.3. Reliability of the CTPCK scores

The score reliability of the CTPCK scale was determined using Cronbach’s alpha coefficient. Confidence intervals (95%) were also evaluated using the method recommended by
Fan and Thompson (2001). According to Henson (2001) and Loo (2001), test scores should have reliabilities of .80 or better. The scale scores had acceptable reliability coefficients (see Table 3).

### 4.4. TPACK description and analysis

In this section, the results about the perceptions of pre-service teachers’ TPACK are presented. Table 3 also shows the eight subscales’ mean scores, varying from 3.99 (SD = 1.19) for CK to 5.11 (SD = 1.31) for TKW. These results suggest that pre-service
teachers’ perceptions about content knowledge were relatively low, while perceptions about World Wide Web knowledge were relatively high.

Finally, the nature of the relationships among research variables can be derived from the bivariate correlation analysis results (see Table 4). For the purpose of this study, TPACK correlations are of primary interest. The results suggest high interrelationships among different variables. For instance, PCK is significantly related to TPACK ($r = .449$); TCK presented the strongest correlation with TPACK ($r = .742$).

### 5. Discussion

In the past decade, much TPACK research has been generated (for an overview, see Voogt et al., 2013). An interesting and remarkable TPACK research development is that researchers have turned their attention away from a messy construct towards a layered construct within the TPACK framework (as presented in Figure 1). However, researchers have commented that TPACK construct boundaries can be rather vague at times, making it difficult to categorise instances of technology integration (Cox & Graham, 2009; Koehler & Mishra, 2009).

A series of studies show reliable outcomes when Schmidt et al.’s TPACK constructs are used and some of them report a very good reproduction of the knowledge domains with factor analysis. However, there are several studies in which the knowledge domains

### Table 4. Correlation coefficients for variable pairs ($n = 436$).

<table>
<thead>
<tr>
<th>Subscale</th>
<th>Number of items</th>
<th>Mean</th>
<th>SD</th>
<th>alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK</td>
<td>4</td>
<td>3.99</td>
<td>1.19</td>
<td>.88</td>
</tr>
<tr>
<td>PK</td>
<td>5</td>
<td>4.62</td>
<td>1.10</td>
<td>.92</td>
</tr>
<tr>
<td>TK</td>
<td>4</td>
<td>4.55</td>
<td>1.26</td>
<td>.92</td>
</tr>
<tr>
<td>PCK</td>
<td>7</td>
<td>4.55</td>
<td>1.10</td>
<td>.94</td>
</tr>
<tr>
<td>TCK</td>
<td>4</td>
<td>4.48</td>
<td>1.14</td>
<td>.89</td>
</tr>
<tr>
<td>TPK</td>
<td>5</td>
<td>4.82</td>
<td>1.06</td>
<td>.91</td>
</tr>
<tr>
<td>TKW</td>
<td>3</td>
<td>5.11</td>
<td>1.32</td>
<td>.85</td>
</tr>
<tr>
<td>TPACK</td>
<td>4</td>
<td>4.46</td>
<td>1.11</td>
<td>.91</td>
</tr>
</tbody>
</table>

Table 4. Correlation coefficients for variable pairs ($n = 436$).

```markdown
<table>
<thead>
<tr>
<th></th>
<th>1 CK</th>
<th>2 PK</th>
<th>3 PCK</th>
<th>4 TK</th>
<th>5 TKW</th>
<th>6 TPK</th>
<th>7 TCK</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 CK</td>
<td></td>
<td>.576**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 PK</td>
<td>.576**</td>
<td></td>
<td>.590**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 PCK</td>
<td>.491**</td>
<td>.590**</td>
<td></td>
<td>.432**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 TK</td>
<td>.446**</td>
<td>.504**</td>
<td>.432**</td>
<td></td>
<td>.524**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 TKW</td>
<td>.202**</td>
<td>.431**</td>
<td>.344**</td>
<td>.524**</td>
<td></td>
<td>.656**</td>
<td></td>
</tr>
<tr>
<td>6 TPK</td>
<td>.384**</td>
<td>.596**</td>
<td>.548**</td>
<td>.673**</td>
<td>.656**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 TCK</td>
<td>.436**</td>
<td>.540**</td>
<td>.393**</td>
<td>.722**</td>
<td>.581**</td>
<td>.690**</td>
<td></td>
</tr>
<tr>
<td>8 TPACK</td>
<td>.500**</td>
<td>.572**</td>
<td>.449**</td>
<td>.701**</td>
<td>.510**</td>
<td>.717**</td>
<td>.742**</td>
</tr>
</tbody>
</table>
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of the TPACK framework could not be reproduced through EFA (e.g., Archambault & Crippen, 2009; Koh et al., 2010). And, as mentioned above, most of the previous studies only report their results without confirmative factor analyses. Besides, an instrument of TPACK in Chinese contexts is needed, since pre-service teachers in different contexts report different knowledge forms of TPACK.

In the present study, the primary purpose was to develop a theoretically based research instrument to measure CTPCK. Based on recent literature reviews about TPACK, an instrument developed by Chai, Ng, et al. (2013) was translated into Chinese. TKW was added to the instrument, considering the Internet’s crucial importance for education today. The 36-item, eight-factor CTPCK was developed based on results obtained from EFA and CFA procedures. The procedures revealed that the instrument’s item construction and the items’ relevance to each other were appropriate.

Based on our findings, pre-service teachers were able to distinguish the overlapping constructs, such as TCK, PCK, and TPACK, which were reported to be problematic in the prior studies of Chai et al. (2010), and Koh et al. (2010). The findings seem to suggest that when the TPACK framework is employed to survey pre-service teachers’ perceived knowledge levels, consideration must be given to the specific pedagogical approaches they intend to employ (Chai et al., 2010). For example, pedagogical considerations and technology use may differ substantially when one is engaged in constructivist-oriented learning, problem-based learning, or inquiry-based learning as opposed to traditional content mastery learning. The former learning types would require more open, content-free technological tools for knowledge construction, while the latter are likely to require content-saturated technologies, such as tutorial packages and electronic drill-and-practices.

Internet technology has been the fastest growing area of information technology in recent years (Keeney, 1999). Effective use of this technology is increasingly considered as a major determinant of competitive advantage, productivity, individual competency, and even critical components of twenty-first century classroom teaching. As reviewed by Lee and Tsai (2010), Web-based instruction has gained wide-reaching recognition among teacher educators and researchers in the area of educational technology, claiming that Web-based instruction can provide learners with distant, interactive, individualised, and inquiry-based learning activities (e.g., Lee & Tsai, 2005; Miller & Miller, 2000; Tsai, 2001). Thus, in the present study, the division of TK of Mishra & Koehler (2006) into two constructs, TK and TKW, emphasises the “W” (i.e., the World Wide Web) in Chinese educational settings. According to this result, it is necessary to consider TKW as a new construct of TPACK in twenty-first century. This may indicate a refined understanding among the pre-service teachers as they were able to distinguish different forms of TK. Theoretically, it implies that specifying the form of technological knowledge may be necessary. The current TK items are adopted from Schmidt et al. (2009) survey and they are very general statements. TK actually encompasses many different forms of knowledge that could form new sub-scales. For example, if one embarks on digital games as a means of intervention to engage unmotivated learners, it would be appropriate to form items that are purely base on game technology. It is obvious that a computer user with good general knowledge about computer could be quite lost in navigating the gaming environment.

The present research has some limitations, which should be addressed in future research. The first limitation of our study is related to the limited pre-service teacher sample, considering the large population of their counterparts in China. Therefore, future
studies should examine whether the factor structure is sufficiently robust. Second, we randomly divided the original research sample in two subsamples to develop this research instrument. Hence, these two subsamples were not truly independent samples. In future research, the modified model should be validated in an independent sample. Third, CTPCK appropriateness should be assessed in a wider variety of contexts. Further CTPCK refinement and evaluation is needed in other educational settings (e.g., with schoolteachers). Finally, the sample size was limited to do split-half factor analyses, since Tabachnick and Fidell (2007) recommend a minimum of 300 cases for a factor analysis. Consequently, a larger sample analysis would be preferable in the future.

In addition, Voogt et al. (2013) argue that pre-service teachers need to demonstrate what they can actually do with technology to enhance teaching and learning of their subjects. Such instruments, however, are not very well developed for research purposes. Finally, additional concurrent validity evidence is needed before the instrument is used extensively. As a recommendation for further research, (pre-service) teachers’ characteristics can be explored as potential CTPCK determinants. Different CTPCK domains could correspond to different teacher characteristics and/or institutional antecedents.

6. Conclusion
Building on the work of Lee and Tsai (2010), Chai et al. (2010), Chai, Koh, Tsai, et al. (2011) and Koh et al. (2010), this study contributes to extant TPACK research by creating a survey with construct validity for the six TPACK constructs postulated by Mishra and Koehler (2006) and an additional construct related to Internet knowledge. Both exploratory and CFAs verified reasonable and acceptable scale construction and validation. The obtained dimensions’ acceptable internal consistency and the strong correlation with related constructs support the notion that the CTPCK provides a useful measure to describe pre-service teachers’ TPACK. Moreover, the instrument can be used to assess TPACK development in teacher education programs.

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References


Appendix

**Technological Pedagogical Content Knowledge of Pre-service Teachers**

师范生整合信息技术的学科教学法知识调查

Part 1 – Content knowledge

(一) 学科知识

CK1 I have sufficient knowledge about my teaching subject.
我对于我所教的科目有足够的知识。

CK2 I can think about the content of my teaching subject like a subject matter expert.
我能够像专家一样思考所教的科目内容。

CK3 I am able to gain deeper understanding about the content of my teaching subject on my own.
我仅靠自己的力量就能更深入地理解所教的科目内容。

CK4 I am confident to teach the subject matter.
我对自己所掌握的学科知识有足够的信心。

Part 2 – Knowledge about teaching methods

(二) 一般教学法知识

PK2 I am able to guide my students to adopt appropriate learning strategies.
我能够指导学生采用适当的学习策略。

PK3 I am able to help my students to monitor their own learning.
我能够帮助学生做到学习上的自我监控。

PK4 I am able to help my students to reflect on their learning strategies.
我能够帮助学生反思他们的学习策略。
PK5 I am able to plan group activities for my students.
    我能够为学生策划一些小组学习活动。
PK6 I am able to guide my students to discuss effectively during group work.
    我能够指导学生在小组活动中有效地讨论问题。

Part 3 – Knowledge about teaching my teaching subjects
    （三）针对我的教学科目的教学知识
PCK1 Without using technology, I can address the common misconceptions my students have for my teaching subject.
    即使不使用多媒体，我也能够处理好所教学科中学生普遍易犯错误的内容。
PCK3 Without using technology, I can help my students to understand the content knowledge of my teaching subject through various ways.
    即使不使用多媒体，我也能够帮助学生利用各种方法理解我所教的学科知识。
PCK4 Without using technology, I can address the common learning difficulties my students have for my teaching subject.
    即使不使用多媒体，我也能够处理学生在我所教的学科中常出现的学习困难。
PCK5 Without using technology, I can facilitate meaningful discussion about the content students are learning in my teaching subject.
    即使不使用多媒体，我也能够促进学生就所学内容进行有意义的讨论。
PCK6 Without using technology, I can engage students in solving real world problem related to my teaching subject.
    即使不使用多媒体，我也能够促使学生解决与我所教学科相关的真实情境问题。
PCK8 Without using technology, I can support students to manage their learning of content for my teaching subject.
    即使不使用多媒体，我也能够协助学生自行管理学习我所教的学科内容。

Part 4 – Knowledge about technology
    （四）多媒体知识
TK1 I have the technical skills to use computers effectively.
    我具有有效使用计算机等多媒体的能力。
TK2 I can learn technology easily.
    我能够轻松地学习多媒体。
TK3 I know how to solve my own technical problems when using technology.
    当使用多媒体时，我知道如何解决自己所面临的多媒体问题。
TK4 I keep up with important new technologies.
    我能不断掌握重要的新多媒体技术。

Part 5 – Knowledge about Web
    （五）网络知识
TK6 I am able to use social media (e.g., Blog, Wiki, Facebook).
    我能够使用网络社群媒体，例如：微博、博客、人人等。
TK7 I am able to use communication tools (Yahoo, IM, MSN Messenger, ICQ, Skype, etc.).

TK8 I am able to use collaboration tools (e.g., Google Sites, Google Doc).

Part 6 – Knowledge about using technology to teach

TPK1 I am able to use technology to introduce my students to real-world scenarios.

TPK2 I am able to facilitate my students to use technology to find more information on their own.

TPK3 I am able to facilitate my students to use technology to plan and monitor their own learning.

TPK4 I am able to facilitate my students to use technology to construct different forms of knowledge representation.

TPK5 I am able to facilitate my students to collaborate with each other using technology.

Part 7 – Knowledge about technology used in my teaching subject

TCK1 I can use the software that is created specifically for my teaching subject. (e.g., e-dictionary; Geometer’s sketchpad for Maths; Data loggers for Science)

TCK2 I know about the technologies that I have to use for the research of content of my teaching subject.

TCK3 I can use appropriate technologies (e.g., multimedia resources, simulation) to represent the content of my teaching subject.

TCK4 I can use specialised software to perform inquiry about my teaching subject.

Part 8 – ICT Integration Knowledge

TPACK3 I can structure activities to help students to construct different representations of the content knowledge using appropriate ICT tools (e.g., Webspiration, Mindmaps, Wiki).

I can use specialised software to perform inquiry about my teaching subject.
I can create self-directed learning activities of the content knowledge with appropriate ICT tools (e.g., Blog, Webquest).

我能够针对学科内容设计电脑辅助学生自主学习（如利用博客，网络探究Webquest等）。

I can design inquiry activities to guide students to make sense of the content knowledge with appropriate ICT tools (e.g., simulations, Web-based materials).

我能够设计探究活动，并以适当的多媒体（例如模拟软件，网络资源）引导学生理解学科知识。

I can design lessons that appropriately integrate content, technology and pedagogy for student-centred learning.

我能恰当整合教学内容、多媒体技术和教学方法来设计教学，实现以学生为中心的学习。