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A Technological Pedagogical Content Knowledge (TPACK) Scale for Geography Teachers in Senior High School

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Abstract

With information technology being employed extensively in school education, the TPACK (Technological Pedagogical Content Knowledge) theoretical framework is adopted by a growing number of researchers to study, assess and advance teachers' ability to integrate IT into course teaching. However, there is no measurement instrument designed specifically to assess Geography teachers' TPACK competences in Mainland China so far. In this study, based on the currently available TPACK measurement instruments, we attempt to develop, following the 7-factor TPACK model, a measurement scale for senior high school Geography teachers in Mainland China. Invitation emails were sent to target teachers and a total of 869 valid responses were received from 9 Mainland provinces. Confirmatory factor analysis was administered on the collected data to attest convergent validity and discriminant validity of the scale, as well as the 7-factor TPACK model. As demonstrated with our research findings, the TPACK knowledge structure of senior high school Geography teachers in Mainland China accords with the 7-factor model, with factor loadings of the 37 measured variables all distributed between 0.57 and 0.94, and composite validity values of each factor ranging between 0.87 and 0.93, which indicates the scale has good convergent validity; after the seven factors being paired with each other, the chi-square value differences between constrained and unconstrained models all reach the significant level of 0.05, which indicates the scale has good discriminant validity.

Keywords

TPACK

Geography teachers

Development of measurement scales

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Introduction

It is important for teachers today to adopt information technology in terms of rapidly integrating Information and Communication Technologies (ICT) into their instructions (Bingimlas, 2009). Based on the technological pedagogical content knowledge (TPACK) theoretical framework introduced by Koehler and Mishra (2005), researchers have studied and developed various instruments over the past decade to measure teachers' TPACK competences, constituent factors and structural relationships (Akman & Güven, 2015; Chai, Ng, Li, Hong, & Koh, 2013; Canbazoğlu Bilici, Yamak,

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Kavak, & Guzey, 2013; Koh, Chai, & Tsai, 2010; Schmidt et al., 2009). These measurement instruments have been proved to be very effective and provide vital information for helping teachers' professional development and refining course content and pedagogical methods for teacher education and training programs.

As argued by Mishra and Koehler (2006), specific teaching contexts (e.g., cultural background, subject matter, etc.) should be taken into account to better understand and develop TPACK for teaching practitioners. Given the fact that TPACK is highly contextualized, Cai and Deng (2015) advocated further studies on the TPACK knowledge structures and development mechanisms of different subject areas that have been conducted in different regions and countries. However, as our literature review reveals, there is no measurement instrument designed specifically for assessing senior high school Geography teachers' TPACK literacy in Mainland China. In this study, we attempt to present a valid TPACK instrument developed specifically for senior high school Geography teachers in Mainland China, by means of translating, modifying and adopting the TPACK measurement instruments currently available in the field.

The notion of TPACK evolves from the construct of pedagogical content knowledge (PCK) introduced by Shulman in 1986. Grounded in the PCK concept, researchers such as Hughes (2005), Niess (2005), Margerum-Leys and Marx (2002) suggested that teachers should develop a nuanced understanding of the relationships between technology, content, and pedagogy, and thus acquire a sound knowledge of integrating technology effectively into their teaching practices. To better illustrate the complex relationships between technology, content, and pedagogy, Mishra and Koehler (2006) proposed a TPACK conceptual framework, as shown in Figure 1. In this conceptual framework, Mishra and Koehler (2006) argued that effective technology integration into pedagogical activities entail the mastery of three core knowledge components (i.e., technological knowledge (TK), pedagogical knowledge (PK) and content knowledge (CK)) and four interrelated components (i.e., technological pedagogical knowledge (TPK), technological content knowledge (TCK), pedagogical content knowledge (PCK), and technological pedagogical content knowledge (TPCK)) derived from the interplaying of the three core components. Considering the fact that these seven components are highly correlative between and among themselves, Cai and Deng (2015) argued that a clear cut definition should be formulated for each TPACK component for the sake of avoiding discrepancy in identifying each individual component and further confusion in interpreting research results.

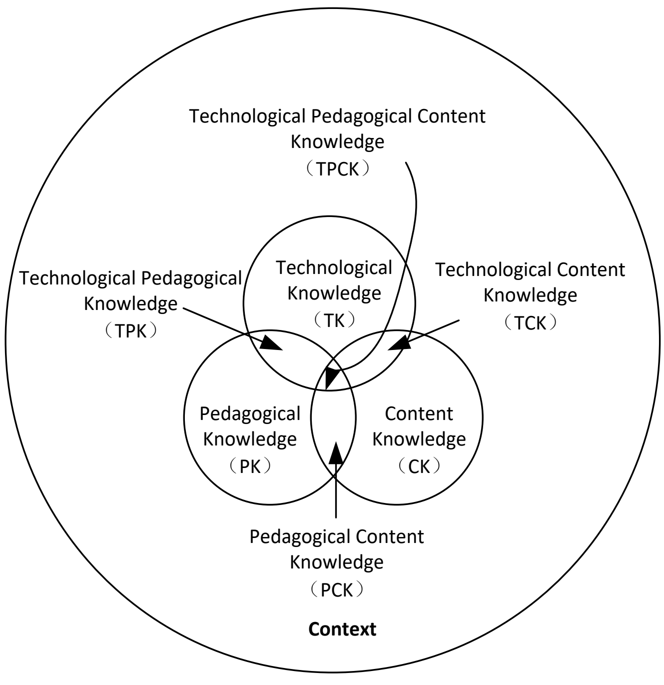

Figure 1. TPACK Framework and Components (Koehler & Mishra, 2009).

A review of related literature shows that the seven TPACK framework components are generally suggested to be defined as follows (Chai, Koh, & Tsai, 2011; Koehler & Mishra, 2009; Shulman, 1986): (1) TK — knowledge about various emerging information technologies (e.g., computer, the Internet) and operation of relevant hardware and software programs; (2) CK — knowledge about the actual subject matter to be learned or taught (e.g., Geography, Chemistry); (3) PK — knowledge about pedagogical processes and methods (e.g., classroom instruction techniques, student characteristics, teaching evaluation strategies); (4) PCK — knowledge about developing appropriate teaching practices for a given subject area; in other words, what pedagogical methods or strategies are best for teaching certain subject areas; (5) TPK — knowledge about how various technologies can be utilized to support specific pedagogical methods or strategies; (6) TCK — knowledge about how information technologies can create new representations for specific subject areas; (7) TPCK — knowledge about how appropriate information technologies and pedagogical methods or strategies can be incorporated to facilitate learning in a given subject area.

Cai and Deng (2015), with extensive literature reviewed, pointed out that empirical studies conducted on TPACK so far generally fall into four categories, namely, generic, technology-specific, pedagogy-specific and content-specific; among them, content-specific studies on TPACK mainly cover disciplines such as Educational Technology, Science and Engineering, and the Humanities (including Geography, History and Social Sciences), with Science and Engineering in the majority. So far, for the subject of Geography, TPACK theoretical framework has been used as a meta-cognitive tool to develop GeoThentic, an online teaching environment, and also used to support the measurement of teachers' TPACK competences (Doering, Scharber, Miller, & Veletsianos, 2009). Hong and Stonier (2015) studied in-service teachers' viewpoints and attitudes towards TPACK-based Geography Information System (GIS) training sessions, but found no research initiatives so far specializing in TPACK measurement instruments and constituent factors exclusively for high school Geography teachers.

Xu, Liu, Wang, and Zhang (2013), after reviewing the literature, reported that scales are the most frequently administered instrument at present to measure and assess the level of teachers' TPACK. To date, a number of scholars (Akman & Güven, 2015; Chai et al., 2013; Canbazoğlu Bilici et al., 2013; Lee & Tsai, 2010; Lin, Tsai, Chai, & Lee, 2013; Koh et al., 2010; Chai, Koh, Tsai, & Tan, 2011; Schmidt et al., 2009) have developed or adapted scales to assess teachers' TPACK competences in different disciplines, probing into TPACK constituent factors and structural relationships between factors studied.

A case of the five-point Likert type scale which contains 75 items designed by Schmidt et al. (2009), was used to survey 124 American pre-service teachers (in four different specialty areas: Math, Social Sciences, Science and Literature). Exploratory factor analysis was conducted separately on each of the seven TPACK factors. The number of items were reduced to 47 with very high internal consistency and construct validity. In addition, the factor of TPCK was found to be significantly correlated with the other six factors, with a high degree of correlation between TPCK and TPK ($r = 0.71$). Chai et al. (2011) built a scale upon what Schmidt et al. (2009) had done and used it to survey Singaporean pre-service teachers' TPACK self-efficacy. Considering the specialties of pre-service teachers who participated in the survey and given the fact that all Singaporean teachers are trained to teach two subjects at a time, adaptations or substitutions were made to the original survey items pertinent to TPK, TCK and CK; and also 13 brand-new items were crafted to replace the existing PK-related ones, including 5 items which reflect the competence of integrating Web technologies into pedagogy, renamed as the pedagogical knowledge for meaningful learning (PKML) factor. A refined scale with 31 items was eventually developed after both exploratory and confirmatory factor analysis of the measured data, which proved to be of sound construct validity.

These various scales have good reliability and validity, but as a matter of fact, the factors involved are not in full compliance with the seven-factor TPACK model postulated by Mishra and Koehler (2006). For instance, taking into account the diverse professional backgrounds that pre-service teachers participating in the study came from, Koh et al. (2010) generalized the formulation of content-specific items in the TPACK scale developed by Schmidt et al. (2009), deleted 11 items determined to be irrelevant and retained all the items pertaining to the factors of TK, PK and TPK; then used exploratory factor analysis to assess the constructs' validity and found a valid 29-item scale which involves 5 factors, namely, TK, CK, KP (Knowledge of Pedagogy), KTT (Knowledge of Teaching with Technology), and KCR (Knowledge from Critical Reflection).

Lee and Tsai (2010) put forward a framework for understanding an measuring in-service teachers' competences of Technological Pedagogical Content Knowledge-Web in the context of web-based teaching and learning, which includes pedagogical knowledge (PK), content knowledge (CK), Web knowledge, Web-Pedagogical knowledge (WPK), Web content Knowledge (WCK), and Web pedagogical content knowledge (WPCK). The exploratory factor analysis results indicated that no WPK (Web-Pedagogical Knowledge) factor was able to be identified. In the end a valid scale that contains 5 factors, with 33 items, was developed after items with factor loadings less than 0.5 or cross-loaded to other factors were removed. The five factors covered in the scale are termed Web-general, Web-communicative, Attitudes, Web-Content Knowledge (WCK) and Web-Pedagogical-Content Knowledge (WPCK). Web-general and Web-communicative are the factors employed to assess teachers' self-efficacy of their Web competence and Attitudes is the factor to evaluate teachers' attitudes towards incorporation of Web-technology into teaching practices.

The differences in research findings can be told from the following facts: (1) Theoretically speaking, researchers have approached the TPACK model from different perspectives: to sum up, "the integrative approach" (TPCK derives from the interaction and interplaying of TK, PK, CK, TPK, TCK and PCK) or "the transformative approach" (TPCK is a distinct or unique body of knowledge, developing alone without relying on TK, PK, and CK) (Graham, 2011); (2) TPACK is deemed as highly situational (Koehler & Mishra, 2005) and thus teachers' identification of different factors will be affected in diverse contexts; (3) Teachers vary from each other in their mastery of subject contents and teaching experiences (Dong, Chai, Sang, Koh, & Tsai, 2015); (4) TPACK constituent factors are not clearly defined (Chai et al., 2013); (5) Different factor analysis methods are employed in the course of data processing. (Cai & Deng, 2015). Therefore, it is suggested that, when it comes to developing new TPACK measurement scales or adopting existing ones, TPACK constituent factors should be explicitly defined and depicted in the first place; and then confirmatory factor analysis is to be implemented to assess both discriminant validity and construct validity of the measurement model (Cai & Deng, 2015); in addition, the theoretical basis followed to develop assessment scales should be specified (Canbazoğlu Bilici et al., 2013).

A case that Chai et al. (2013) had done based on "the transformative approach" adopted the existing scale (Chai et al., 2011). In the adopting process, the conceptual differences between items under different factor categories were elaborately formulated. The adapted scale was administered to measure the TPACK level of 550 pre-service teachers from Mainland China, Hong Kong, Taiwan and Singapore and the results were reported to accord with the seven-factor TPACK model proposed by Mishra and Koehler (2006).

The high school Geography curriculum in Mainland China covers both Human Geography and Earth Science (Chen & Fan, 2002). With this and the diverse cultural backgrounds in Mainland China taken into consideration, we attempt to put forward a seven-factor TPACK measurement scale by translating, modifying and adopting the ones available in the current literature; and building upon this, we attempt to attest whether the TPACK knowledge structure of Chinese Mainland senior high school Geography teachers conforms to the seven-factor TPACK model (TK, CK, PK, TCK, TPK, PCK, and TPCK) proposed by Mishra & Koehler (2006), and develop a measurement scale for senior high school Geography teachers in Mainland China, with convergent validity and discriminant validity tested.

Method

Sample

Geography courses, with subjects ranging from Earth and Atlas, World Geography, Chinese Geography to Local Geography, are compulsory right now for all seventh-and-eighth graders at junior high schools in Mainland China. As for senior high school students, the curriculum involves both compulsory and optional courses. At the tenth Grade, all students are required to take the compulsory course which is composed of three modules: Geography 1, Geography 2, and Geography 3, covering subjects include Physical Geography, Human Geography and Regional Geography. The optional course, consisting of seven modules: Universe and the Earth, Ocean Geography Natural Disasters & Precautions, Tourism Geography, Urban & Rural Planning, Environmental Protection, and Application of Geographic Information Technology, is available for the students who are going to choose Geography as one of the subjects to be tested in their 2-day college entrance examination (also known as Gaokao) in the final year of high school. They are obliged to take at least two out of the aforementioned seven elective modules at either eleventh or twelfth Grade. As Geography is not being included in the high school entrance exam (also known as Zhongkao) in Mainland China currently, it receives very little attention from both school authorities and students. As a result, quite a few junior high school teachers in China are not specializing in the subject of Geography and having insufficient knowledge of subject matters. It is in such a context that our current study is designed to focus only on senior high school teachers.

Due to the fact that there are obvious differences in terms of economy and education among the eastern, central and western areas of Mainland China, our study is designed to reflect the overall landscape of Geography teaching in senior high schools in Mainland China as accurate as possible. The provinces involved in this study are selected respectively from Eastern, Central and Western China; namely, Guangdong, Fujian, Zhejiang, Shanghai, and Shandong from the eastern area; Anhui, Henan, and Inner Mongolia from the central area; and, Chongqing from the western area. Instructional coaches of Geography at the provincial level and instructors of Geography Pedagogy from universities were commissioned to send emails to local senior high school Geography teachers in their areas, inviting the teachers to participate in the survey. Participation was voluntary and respondents were directed to access the designated survey-publishing website and complete the survey posted online. Finally, a total of 895 responses, among which 869 were valid, were received. The teachers who responded to the survey are distributed across nine provinces in Mainland China. As for the valid responses, 43.7% (n = 380) are from male teachers and 56.3% (n = 489) are from female teachers; 56.6% (n = 492) of respondents are from schools located in the municipalities, capital cities or prefecture-level cities and the rest 43.4% (n = 377) are from schools located in the counties or towns; of all the respondents, 96.8% (n=841) are teachers with Geography background, while the rest 3.2% do not specialize in Geography.

Research Instrument

Chai et al. (2013), while studying TPACK constituent factors and factor structures among pre-service teachers in Chinese Asian regions, developed a scale containing 31 items (available both in Chinese and English), with "the transformative approach" as the theoretical framework. In the said study, the pre-service teachers in Chinese Asian regions are found to be able to identify all the seven TPACK factors postulated by Koehler and Mishra (2009) fairly well. Considering the similarities in teacher subjects' cultural backgrounds, this study first adopted all the items for the four factors of TK, CK, TCK and TPCK (17 items), 3 items for the PK factor and 1 item related to the PCK factor in the scale developed by Chai et al. (2013). The following modifications then were made to the scale items: (1) In all the question items, "technology" was replaced by "information technology" so that the connotation of "technology (T)" is made more explicit; (2) the "subject content knowledge (CK)" is explicated precisely as "the subject of Geography and the subject content of high school Geography"; (3) scenarios of Geography studies are added to certain question items to improve the accuracy of statements, taken as an example here, "I can use software tools specifically designed for the subject of Geography to represent Geography teaching content (such as Google Earth, Virtual Planetarium, etc.)."

On top of that, given that school authorities in Mainland China are vigorously motivating teaching staffs to integrate information technology to promote classroom interaction, access student feedback and facilitate personalized learning, the following three categories of items were added to the scale. (1) Adding items PCK4 (Akman & Güven, 2015), PCK5 (Canbazoğlu Bilici et al., 2013), PK5 (Schmidt et al., 2009) and PK7, which are designed to measure teachers' knowledge about educational evaluation. Educational evaluation always plays a leading role in the cause of education reform and the information generated therefrom serves to facilitate teachers' decision-making, measuring student academic achievements and conducting educational research (Edelson, Shavelson, & Wertheim, 2013). With rapid technological advancement in fields of computer, network, big data mining and learning analytics, information technology bears ever-increasing significance in educational evaluation (Daly, Pachler, Mor, & Mellar, 2010). (2) Adding items CK4, TK1, TPK5 (Schmidt et al., 2009), PCK2 (Canbazoğlu Bilici et al., 2013), TK5 and TK7, which attempt to measure teachers' confidence and learning ability with regard to TPACK. Information technology is a domain that witnesses a most rapid development and entails teachers' continuous update of their TPACK competences through teaching practices, which inevitably highlights teachers' learning ability and confidence concerning TPACK. (3) Adding items that deal with how information technology facilitates individualized teaching and enhances classroom interaction. For instances, the item PK2 asks "I can apply different pedagogical techniques (e.g., brainstorming, experimental demonstration, action modelling, analogy drawing, etc.) (Akman & Güven, 2015) for varying instructional contexts (e.g., different course contents, student pre-entry performance, etc.) and the item TPK2 asks "I am capable of utilizing information technology to improve classroom interaction" were added. For the items, originally in English, were first translated into Chinese by a bilingual university research faculty member specializing in High School Geography Education, and then revised and polished by the authors of the study. A bilingual expert in the field is entrusted to translate the items back into English and ensure no meaning has been changed due to the translation. With all these adaptations and modifications, the first draft scale which comprises 40 seven-point Likert items took shape initially (see Appendix 1).

Procedure

The list of items was sent to an expert committee of nine members for content validity review. Among them, two are experts in educational technology; two are high school teaching experts of Geography, and the rest of five are educational researchers of high school Geography. Adaptions and modifications are further made to items according to committee's feedback. The seven-point Likert-type scale was adopted in this case and a questionnaire consisting of 40 question items was drafted as the instrument. Then the questionnaire was posted online on a survey website; meanwhile, invitation emails were sent to senior high school Geography teachers in 9 provinces in Mainland China. The teachers who received the invitation accessed the online survey to complete the questionnaire on a voluntary basis.

Data Analysis

Exploratory factor analysis (EFA) is a statistical method used mainly for theoretical output, while confirmatory factor analysis (CFA) is more advisable for testing existing theories (Hair, Black, Babin, & Anderson, 2010). As the TPACK seven-factor model already has a solid theoretical basis (Mishra & Koehler, 2006), it is suggested that only the CFA be performed in the follow-up TPACK studies, which means the discriminant validity and structural validity of the factors are to be assessed by the fitness of the seven-factor model and the collected data (Cai & Deng, 2015). This study is based on the TPACK seven-factor model originally proposed by Mishra and Koehler (2006), from which the items are adapted and developed. Therefore, in our study, the approach of Maximum Likelihood Estimates (ML) was administered to run the confirmatory factor analysis on the seven-factor model postulated by Mishra & Koehler (2006), with all data processed with SPSS Amos (version 21.0). The values of goodness-of-fit index χ^2/df, RMSEA, TLI and CFI are extracted to determine the fitness of the model (Chai et al., 2013). χ^2/df value less than 2 indicates a good fit for the model (Kline, 2011) and a value less than 5 is interpreted as an acceptable fit (Akman & Güven, 2015). Among these fit indices, the RMSEA is believed to be a fairly good absolute fit index as its dependence on sample size is relatively small, the smaller the value, the better the fit is (Hou, Wen, & Cheng, 2004). Steiger (1990) argues that a RMSEA value less than 0.1 represents a good fit, and less than 0.05 indicates a very good fit. As far as TLI and CFI indices are concerned, the closer the value is to 1, the better the model fit is, with a value greater than 0.9 generally indicating that the model has a good fit (Hair et al., 2010).

Convergent validity and discriminant validity of the 7-factor TPACK model are tested. Convergent validity can be established if measured variables (indicator variables) of the same factor (latent construct) load strongly on their common construct, along with high factor loading values attained on the factor of interest, and measured variables highly correlated with each other (Wu, 2013). Convergent validity through confirmatory factor analysis can be assessed with factor loading (λ) and composite reliability (ϱ_c) (Hair et al., 2010). As suggested by Hair et al. (2010), a considerably great factor loading value indicates that items of the scale instrument have good convergent validity. In general, the factor loading value should be above 0.5 or more (Chai et al., 2013; Wu, 2013); A factor loading value greater than 0.71 indicates the scale items have desirable quality (Hair et al., 2010). Composite reliability of latent constructs (factors) is usually required to be greater than 0.6 (Fornell & Larcker, 1981). The greater composite reliability, the more correlated the set of measured variables, i.e., the more homogenous they are.

As has been noted by Hair et al. (2010), the factors assessed with confirmatory factor analysis must demonstrate good discriminant validity, i.e., factors should be effectively differentiated from each other. In the present study, the Chi-square difference test is implemented to determine whether the scale has good discriminant validity or not; that is to say, Chi-square values of the constrained model (with the correlation coefficient between two factors constrained to 1) and the unconstrained model (with the correlation coefficient between two factors as freely estimated parameters) are put in comparison. A significantly great difference between the Chi-square values ($\Delta\chi^2 > \chi^2_{0.05} = 3.841, p < 0.05$) indicates that the two factors are not fully correlated and thus are deemed discriminative (Anderson & Gerbing, 1988; Wu, 2013).

Results

Descriptive Statistics

The descriptive statistical analysis was performed on the 40 measurement variables, with the results demonstrated in Table 1. As can be seen from Table 1, except the variable TK2 (Kurtosis = 6.006), all Kurtosis coefficients of the other 39 measurement variables assume normal distribution, no greater than the critical value (< 5) suggested by Bentler (2006). TK2 was then removed, following recommendations by Chai et al. (2013). Subsequently, the Cronbach's alpha coefficient was utilized to test the internal consistency of each sub-scale of the measurement instrument. The Cronbach's alpha coefficient for each subscale of TPACK's seven factors is, respectively, TK (0.87), PK (0.87), CK (0.82), PCK (0.91), TPK (0.89), TCK (0.86), TPCK (0.92), which indicates the measurement scale enjoys good internal consistency (Hair et al., 2010).

Table 1. Descriptive Statistics

Item	**N**	**Mean Value**	**Standard Error**	**Kurtosis**	
	Statistics	**Statistics**	**Statistics**	**Statistics**	**Standard Error**
TK1	869	3,78	1,754	-1,211	0,166
TK2	869	6,18	1,088	6,006	0,166
TK3	869	4,26	1,566	-0,733	0,166
TK4	869	4,27	1,518	-0,730	0,166
TK5	869	4,20	1,667	-0,917	0,166
TK6	869	4,29	1,536	-0,695	0,166
TK7	869	5,04	1,447	0,327	0,166
PK1	869	5,50	1,039	2,075	0,166

Table 1. Continued

Item	N	Mean Value	Standard Error	Kurtosis	
	Statistics	Statistics	Statistics	Statistics	Standard Error
PK2	869	5,22	1,156	1,344	0,166
PK3	869	5,60	1,007	3,083	0,166
PK4	869	5,22	1,071	1,248	0,166
PK5	869	5,40	1,033	1,898	0,166
PK6	869	4,52	1,404	-0,442	0,166
PK7	869	5,06	1,256	0,566	0,166
CK1	869	5,28	1,122	1,014	0,166
CK2	869	5,58	0,989	1,613	0,166
CK3	869	5,50	1,021	1,430	0,166
CK4	869	5,52	0,998	1,067	0,166
CK5	869	4,80	1,273	0,040	0,166
PCK1	869	4,99	1,155	0,240	0,166
PCK2	869	5,29	1,083	1,085	0,166
PCK3	869	5,04	1,172	0,269	0,166
PCK4	869	5,06	1,155	0,479	0,166
PCK5	869	5,12	1,125	0,597	0,166
TPK1	869	5,54	1,119	1,936	0,166
TPK2	869	5,30	1,104	1,467	0,166
TPK3	869	5,46	1,033	2,337	0,166
TPK4	869	5,43	1,047	2,221	0,166
TPK5	869	5,31	1,167	1,429	0,166
TPK6	869	5,26	1,092	1,280	0,166
TPK7	869	4,75	1,287	-0,132	0,166
TCK1	869	4,41	1,528	-0,607	0,166
TCK2	869	4,96	1,213	0,431	0,166
TCK3	869	5,09	1,203	0,617	0,166
TCK4	869	4,51	1,439	-0,534	0,166
TPCK1	869	4,66	1,384	-0,343	0,166
TPCK2	869	4,83	1,366	-0,118	0,166
TPCK3	869	4,68	1,374	-0,332	0,166
TPCK4	869	4,95	1,275	0,387	0,166
TPCK5	869	4,56	1,448	-0,454	0,166

Model Fit Test

Confirmatory factor analysis with ML is employed to assess the 7-factor model (M_1), which contains 39 measured variables after the deletion of TK2. The factor loadings of measured variables, with the exception of TK7 ($\lambda = 0.46$) and TPK7 ($\lambda = 0.49$), are all distributed between 0.57 and 0.93. Model M_2 was obtained after removing TK7. The ML approach is administered again for confirmatory factor analysis of M_2, with factor loadings of all the measured variables, apart from TPK7 ($\lambda = 0.49$), ranging between 0.57 and 0.93. Model M_3 was then formed after the removal of TPK7, with the ML confirmatory factor analysis following up. This time, the factor loadings of measured variables are found to be distributed, with no exception, between 0.57 and 0.94. The factor loadings of measured variables in M_1, M_2, M_3 are specified in Appendix 2 and the model fit indices are recorded in Table 2. According to discussions made by Akman and Güven (2015), Steiger (1990) and Wu (2013) on fit indices and model fit, model M_3 is considered acceptable, which indicates the TPACK knowledge structure of Chinese Mainland senior high school Geography teachers accords with what is postulated in the 7-factor TPACK model by Mishra and Koehler (2006).

Table 2. A Comparison of Fit Indices Before and After Model Adjustment

Model	χ^2	df	χ^2/df	TLI	CFI	RMSEA	Note
M_1	3073,803	681	4,514	0,891	0,900	0,064	Original Model
M_2	2886,967	644	4,483	0,896	0,905	0,063	TK7 removed
M_3	2478,786	608	4,077	0,911	0,919	0,060	TK7 & TPK7 removed

Note. Fit index χ^2/df less than 5 indicates an acceptable model fit (Akman & Güven, 2015); RMSEA less than 0.1 indicates a good model fit (Steiger, 1990); TLI and CFI indices greater than 0.9 indicate a model with good fit (Hair et al., 2010).

Convergent Validity Test

As can be seen from Appendix 2, the standardized factor loadings of all the measured variables in model M_3 are within the range between 0.57 and 0.94, indicating that all measurement items have a fairly good convergent validity (Wu, 2013). Apart from TK1 (0.57), PK7 (0.57), TPK1 (0.59), TPK5 (0.60) and PK6 (0.63), the standardized factor loading values of the rest were all greater than 0.71, which is interpreted as a desirable quality for most measurement items (Hair et al., 2010). The composite reliability (ρ_c) of each factor was calculated with the standardized factor loadings of measured variables in model M_3, using the following formula (Fornell & Larcker, 1981):

$$\rho_{c=}\frac{(\sum\lambda)^2}{[(\sum\lambda)^2+\sum(\theta)]}$$

They are, respectively, TK (0.89), PK (0.88), CK (0.90), PCK (0.91), TPK (0.93), TCK (0.87), and TPCK (0.91). As the composite reliability of all seven factors is greater than 0.8, which indicates a good homogeneity for all the measured variables (Chai et al., 2013; Wu, 2013). Both standardized factor loadings and composite reliability values demonstrate that the measurement scale has good convergent validity, measured variables can effectively reflect the corresponding factors (latent constructs), and measured variables for the same factors (latent constructs) enjoy high internal consistency (Wu, 2013).

Discriminant Validity Test

Pairwise combining the seven factors of TK, CK, PK, PCK, TCK, TPK and TPCK gives rise to 21 CFA hypothesized models. The constrained and the unconstrained model are attained respectively with covariance for two factors set to 1 and with covariance being a freely estimated parameter. Then the ML approach is adopted to run confirmatory factor analysis on both M_C and M_U to obtain values of χ^2 and df, along with the differences, with the results shown in Table 3. As can be seen in Table 3, the chi-square value differences between constrained and unconstrained models for the seven factors are all above the critical indicator $\chi^2_{0.05}=3.841$ for discriminant validity tests. The fact that the chi-square value differences between constrained and unconstrained models all reach the significant level of 0.05 indicates that the latent traits among seven factors bear significant differences and the factors in the scale exhibits good discriminant validity (Anderson & Gerbing, 1988; Wu, 2013).

Table 3. Excerpt of Discriminant Validity Test for Factor-Pairs

	Statistics							
	Constrained Model (M_U) (The correlation coefficient set to 1)			Unconstrained Model (M_C) (The correlation coefficient as freely estimated parameter)			Chi-square Value Differences (M_U−M_C)	Degree of Freedom differences
Paired Factors	ρ_2	df	χ^2	ρ_1	df	χ^2	$\Delta\chi^2$	Δdf
TK—CK	1,00	35	1876,59	0,48	34	249,51	1627,08 ***	1
TK—PK	1,00	54	1812,32	0,53	53	457,73	1354,59 ***	1
TK—PCK	1,00	35	2319,19	0,31	34	171,40	2147,79 ***	1
TK—TCK	1,00	27	916,66	0,66	26	146,84	769,82 ***	1
TK—TPK	1,00	44	2246,43	0,42	43	298,69	1947,74 ***	1

Table 3. Continued

	Statistics							
	Constrained Model (MU) (The correlation coefficient set to 1)			Unconstrained Model (MC) (The correlation coefficient as freely estimated parameter)			Chi-square Value Differences (MU−MC)	Degree of Freedom differences
Paired Factors	ρ_2	df	χ^2	ρ_1	df	χ^2	$\Delta\chi^2$	Δdf
TK—TPCK	1,00	35	1601,16	0,60	34	214,17	1386,99 ***	1
CK—PK	1,00	54	1052,73	0,74	53	424,13	628,60 ***	1
CK—PCK	1,00	35	1490,86	0,62	34	255,52	1235,34 ***	1
CK—TCK	1,00	27	1168,31	0,58	26	241,75	926,56 ***	1
CK—TPK	1,00	44	1774,45	0,60	43	370,06	1404,39 ***	1
CK—TPCK	1,00	35	1813,48	0,53	34	284,14	1529,34 ***	1
PK—PCK	1,00	54	1754,18	0,57	53	321,33	1432,85 ***	1
PK—TCK	1,00	44	1214,11	0,59	43	336,24	877,87 ***	1
PK—TPK	1,00	65	1745,26	0,63	64	411,90	1333,36 ***	1
PK—TPCK	1,00	54	1643,45	0,60	53	378,85	1264,60 ***	1
PCK—TCK	1,00	27	1402,91	0,45	26	190,54	1212,37 ***	1
PCK—TPK	1,00	44	2462,96	0,50	43	326,55	2136,41 ***	1
PCK—TPCK	1,00	35	2448,54	0,43	34	208,36	2240,18 ***	1
TCK—TPK	1,00	35	1120,68	0,70	34	421,74	698,94 ***	1
TCK—TPCK	1,00	27	592,78	0,82	26	228,41	364,37 ***	1
TPK—TPCK	1,00	44	1908,27	0,65	43	358,26	1550,01 ***	1

Note. * With chi-square value differences between constrained and unconstrained models ($\Delta\chi^2$) greater than 3.841, reaching the significant level of 0.05; *** With chi-square value differences between constrained and unconstrained models ($\Delta\chi^2$) greater than 10.828, reaching the significant level of 0.001.

Outcomes and Discussion

In this study, following the TPACK theoretical framework proposed by Mishra and Koehler (2006) and the prevalent transformative approach to the TPACK, based upon the scale developed by Chai et al. (2013), we attempt to adapt and develop a measurement scale of the 7-factor TPACK model specifically for senior high school Geography teachers in Mainland China. 869 senior high school Geography teachers from nine provinces in Mainland China were participated in this study. The collected data were processed with confirmatory factor analysis.

This study indicates: (1) the TPACK knowledge structure of senior high school Geography teachers in Mainland China conforms to what Mishra and Koehler (2006) proposed in their 7-factor model (TK, CK, PK, TCK, TPK, PCK and TPCK), is also in consistence with what Chai et al. (2013) found in their research studies; (2) the final version of our TPACK measurement scale comprises seven factors, with 37 measurement question items, respectively, TK (5 items), CK (5 items), PK (7 items), TCK (4 items) , TPK (6 items), PCK (5 items), and TPCK (5 items); (3) standardized factor loadings of the 37 measured variables are all distributed between 0.57 and 0.83, with composite validity values for each factor ranging between 0.87 and 0.93, which shows that the measurement scale has good convergent validity; (4) Chi-square value differences between the restricted and unrestricted models for the seven factors all reach a significant level of 0.05, which indicates that the measurement scale has good discriminant validity. In conclusion, the measurement scale can be used as a reliable instrument to assess the status quo of TPACK competences of senior high school Geography teachers in Mainland China, and facilitate their TPACK self-efficacy and self-advancement. The scale also can be used as a foundation for training agencies to develop and adjust their training materials in the domain of applying information technology into teaching practices.

In the finished TPACK scale, the standardized factor loads of most measured variables are found to be greater than 0.71, which is interpreted as a sound quality for the scale items. But factor loadings of TK1, PK7, TPK1, TPK5 and PK6 fail to reach this level, which may be attributable to the status quo of senior high school Geography teaching in Mainland China as discussed here below. In the first place, current application of information technology in Geography teaching still lacks variety, and curriculum integration lacks depth as well (The Strategic Research Base of Education Informatization (Central China) [EISR], 2015). A large number of teachers have no experience of the technologies mentioned in the question items, which may have a negative impact on their perception and judgment of the survey items. For instance, to employ technologies such as 3D Printing and Virtual Reality as described in TK1 in Geography teaching is still in the exploratory stage, with a lot of teachers lacking in hands-on experiences in real-life situations. Secondly, routine evaluation tools of Geography teaching are generally developed by the Teaching & Research Office affiliated with local educational administrative agencies and it is on rare occasions that Geography teachers are obliged to develop on their own, which may affect teachers' perceptions of PK7. Thirdly, the articulation of survey items tends to be abstract and general, which may impede teachers' interpretation of the question items. Take as an example, "critical perspectives" as mentioned in TPK5, and "challenging tasks" as stated in PK6 are considered far from concrete, which may result in divergence of teachers' understanding of those question items. Therefore, in the follow-up research and application of the TPACK measurement scale, it is of high necessity to further modify these questions items for the improvement of the quality of survey items.

It is evidenced that the TPACK knowledge structure of senior high school Geography teachers in Mainland China is in accordance with the seven-factor model proposed by Mishra and Koehler (2006), but not consistent with some research findings concerning TPACK factors (Koh et al., 2010; Canbazoğlu Bilici et al., 2013) and may be caused by the following facts. On the one hand, teachers participating in this study enjoy rich experiences of senior high school Geography teaching; in addition, the educational institutions and administrative agencies in Mainland China are endeavoring to encourage teachers to actively incorporate information technologies to support classroom instruction. Dong et al. (2015) found, when comparing the TPACK factors' structural relationships of pre-service and in-service teachers in Mainland China, the in-service teachers' TPACK self-efficacy is generally better than the pre-service teachers', as they believed, which may come down to the fact that the mastery of subject contents of different teachers is related to their different teaching experiences. The good sense of TPACK self-efficacy of the teachers in Mainland China is deemed helpful for them to identify different TPAC factors. On the other hand, administrative departments of education in Mainland China all attach great importance to enhancing primary and secondary school in-service teachers' competences in technology integration and subject instruction through teacher training programs (Ministry of Education of the People 's Republic of China, 2013). Cai and Deng (2015) argued that teachers' involvement in training is likely to exert influence on their TPACK factor structural relationships; while studies by Lee and Tsai (2010) also pointed out that teachers' ability to identify TPACK factors may be affected if teachers lack IT-related pedagogical knowledge or schools fail to place sufficient emphasis on faculty pedagogical training. Administrative departments of education in Mainland China are vigorously implementing training projects for high school teachers in a systematic manner, and promoting high school Geography teachers' competence of integrating information technology into curriculum teaching, both technically and theoretically, which is conducive to teachers' understanding of survey questions and identification of various TPACK factors.

The present study is designed to develop a scale specifically for evaluation of the TPACK level and self-efficacy of senior high school Geography teachers in Mainland China, with the measurement model fitness tested and the scale's convergent validity and discriminant validity verified as well. But no further analysis is conducted with reference to the structural relationships among the seven TPACK constituent factors and the possible presence of any other factors of influence. As a follow-up to this study, further investigations are to be carried out, through validation of the seven-factor TPACK structural models, to explore the predictive effect between and among TK, PK, CK, TPK, PCK, TCK and TPCK, to assess the TPACK level of Chinese Mainland senior high school Geography teachers, and to provide effective evaluation tools for educational and training institutions to make adjustments to the content structure of their teacher training and development programs.

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Appendix 1. TPACK Scale for Geography Teachers in senior High School

Factor	Item
TK	TK1. I know a variety of information technologies (such as 3D printing, virtual reality, Google googles, etc.)
	TK2. I have the ability to effectively use conventional information technologies (such as PPT, Word, QQ, e-mail, Internet search and information download, etc.)
	TK3. While using information technology, I know how to troubleshoot encountered technical problems.
	TK4. I can learn a new information technology easily.
	TK5. I can self-learn how to use computer applications.
	TK6. I can catch up with new important IT developments.
	TK7. I know the information technologies I need to use.
PK	PK1. I can use different pedagogical methods (such as case study, problem-based exploration, geographical observation, role play, geographical survey, etc.) for specific situations (such as teaching content, student level, etc.)
	PK2. I can apply different pedagogical techniques (e.g., brainstorming, experimental demonstration, action modelling, analogy, etc.) according to specific situations (such as teaching content, student level, etc.)
	PK3. I can guide students to adopt appropriate learning strategies (such as memorizing the contour of provinces and regions with the help of visual images).
	PK4. I can guide students to discuss subject topics effectively in group activities.
	PK5. I know how to evaluate students' performance in classroom.
	PK6. I can design challenging tasks to facilitate students thinking more.
	PK7. I can develop routine assessment tools for Geography teaching (such as multiple-choice questions, short answer questions, evaluation rubrics for student works etc.)
CK	CK1. I have enough knowledge of Geography.
	CK2. I fully understand the main content of the high school Geography curriculum.
	CK3. I can rely on myself to have a more in-depth understanding of the high school Geography curriculum.
	CK4. I have a variety of methods and strategies to improve my understanding of Geography.
	CK5. I can reflect upon the Geography curriculum content in the way a Geography expert does.
PCK	PCK1. Even without the use of information technologies, I can help students solve the real-world problems related to the subject of Geography.
	PCK2. Even without the use of information technologies, I can break down the teaching objectives of each subject area in the Geography curriculum.
	PCK3. Even without the use of information technologies, I can guide students to carry out theme-based geographical inquiry activities.
	PCK4. Even without the use of information technologies, I can select appropriate evaluation tools to assess student performance of learning Geography.
	PCK5. Even without the use of information technologies, I can determine what geographical concepts need to be evaluated in the study of Geography.
TPK	TPK1. I can choose appropriate information technologies to optimize Geography teaching (such as using animation to demonstrate the regression motion of the subsolar point).
	TPK2. I can utilize information technologies to improve classroom interaction.
	TPK3. I can use information technologies to enhance students' enthusiasm for learning.
	TPK4. I can use information technologies to engage students to actively participate in classroom activities.

Factor	Item
	TPK5. I see the use of information technologies in classroom from a critical perspective.
	TPK6. I can adaptively use information technologies in various teaching activities.
	TPK7. I can select appropriate information technologies to optimize Geography teaching (such as using Google Earth to support the geographical inquiry).
TCK	TCK1. I can use Geography-specific software tools to demonstrate Geography subject content (such as Google Earth, virtual planetarium, etc.)
	TCK2. I know what information technologies can be applied to teach Geography.
	TCK3. I can use proper information technologies to represent Geography subject content (such as multimedia resources, simulation software, etc.)
	TCK4. I can use Geography-specific software to conduct Geography-related inquiry activities.
TPCK	TPCK1. I can plan activities according to Geography curriculum, and help students apply proper information technologies to construct various representations of content knowledge (such as the use of mind-mapping, Wikipedia, etc.)
	TPCK2. I can design IT-supported autonomous learning activities for specific Geography course content (such as the use of blogging, online searching, etc.)
	TPCK3. I can design inquiry-based activities, and apply appropriate information technologies (such as simulation software and Internet-based materials) to facilitate students' understanding of Geography course content.
	TPCK4. I can design courses that integrate proper Geography subject contents, information technologies and pedagogical methods, following the student-centered teaching philosophy.
	TPCK5. I can design and assign geographic topics relevant discussion activities and promote collaborative learning among students via appropriate information technologies (e.g., Google, QQ, or discussion forums).

Appendix 2. Model M_1, M_2, M_3 and Their Factor Loadings of Measured Variables

Factor	Measured Variables	Standardized Factor Loadings		
		M_1	**M_2**	**M_3**
TK	TK1	.58	.57	.57
	TK3	.76	.76	.76
	TK4	.84	.84	.84
	TK5	.84	.85	.85
	TK6	.87	.87	.87
	TK7	.46	/	/
PK	PK1	.77	.77	.77
	PK2	.76	.76	.76
	PK3	.74	.74	.74
	PK4	.78	.78	.78
	PK5	.73	.73	.73
	PK6	.63	.63	.63
	PK7	.57	.57	.57
CK	CK1	.76	.76	.76
	CK2	.81	.81	.81
	CK3	.84	.84	.84
	CK4	.82	.82	.82
	CK5	.69	.69	.69
PCK	PCK1	.72	.72	.72
	PCK2	.83	.83	.83
	PCK3	.85	.85	.85
	PCK4	.87	.87	.87
	PCK5	.84	.84	.84
TPK	TPK1	.60	.60	.59
	TPK2	.85	.85	.85
	TPK3	.92	.92	.93
	TPK4	.93	.93	.94
	TPK5	.60	.60	.60
	TPK6	.76	.76	.75
	TPK7	.49	.49	/
TCK	TCK1	.75	.75	.75
	TCK2	.80	.80	.80
	TCK3	.78	.78	.78
	TCK4	.81	.81	.81
TPCK	TPCK1	.84	.84	.84
	TPCK2	.82	.82	.82
	TPCK3	.87	.87	.87
	TPCK4	.82	.82	.82
	TPCK5	.79	.79	.79