Tan, S. C. et al. (Eds.) (2013). Workshop Proceedings of the 21st International Conference on Computers in Education. Indonesia: Asia-Pacific Society for Computers in Education

Development of the Chinese Pre-service Teachers' Technological Pedagogical Content Knowledge Scale

Guoyuan SANG[a], Yan DONG[a*], Ching Sing CHAI[b] & Ying ZHOU[a]
[a] *Faculty of Education, Beijing Normal University, China*
[b] *National Institute of Education, Singapore*

*corresponing.author

Abstract: In this article the development and validation of the Chinese Pre-service Teachers' Technological Pedagogical Content Knowledge Scale (CTPCK) are described. The CTPCK is a 42-item scale for assessing pre-service teachers' knowledge with or without linking educational technology. The sample was split into two subsamples on random basis (n1 = 229, n2 = 207) for having, (1) Exploratory Factor Analysis (EFA) and (2) Confirmatory Factor Analysis (CFA), respectively. After the EFA, the CTPCK scale excluded 4 items and had 8 factors. Reliability and correlations were discussed. The findings revealed that the CTPCK scale was a valid and reliable instrument for measuring TPACK of Chinese pre-service teachers.

Keywords: TPACK; teacher education; exploratory factor analysis; confirmatory factor analysis

1. Introduction

Since recent decades, researchers (e.g., Godfrey, 2001; Becker, 2000) stress the potential of educational technology using in educational contexts to enrich learning environments, to foster flexible knowledge construction, to cater for individual differences (Godfrey, 2001), and to improve the quality of education. In order to reach those aims of using educational technology, school teachers should be prepared for successful integration of educational technology into their teaching practices.

Technological pedagogical content knowledge (TPACK) has been a burgeoning focus of research especially among teacher educators and researchers who are working in the field of educational technology (Chai, Koh, Tsai, 2013).

By understanding the relative influences of these different factors, teacher educators can better support ICT program design and evaluation. However, such kinds of studies have not often been carried out as many TPACK surveys are still in the process of construct validation (see Graham et al., 2009; Schmidt et al., 2009).

As Kabakci Yurdakul et al. (2012) pointed out, the approaches related to technology integration in education have transformed from technocentric integration to techno-pedagogical integration. However, researchers argue that student teachers in China are not being well prepared with TPACK since they are being offered courses mainly focusing on "hard technology" (e.g, Microsoft Office, Flash) knowledge separating from specific educational contexts (Zhan & Ren, 2011).

The key objective of this article is to have a better understanding of student teachers' perception about TPACK. This can be related to the improvement of quality of student teachers and the potential success of educational reforms in China.

2. Theoretical background

2.1 Defining TPACK

Already in 2001, the term technological pedagogical content knowledge (TPCK) was used to define technology integration in classroom (Keating & Evans, 2001; Pierson, 2001). As a framework of describing the professional knowledge of teaching with technology, was again introduced by Koehler and Mishra (2005).

Originally, TPCK is derived from Shulman's (1986) well-known work on Pedagogical Content Knowledge (PCK), which has been considered a unique feature of teachers' professional level – teachers are able to integrate subject knowledge with appropriate pedagogical approaches so that learners are able to understand the subject (Voogt, Pareja Roblin, & Tondeur et al., 2013). TPCK adds technology related knowledge (TK) as an indispensable part of teachers' profession, in the age of information and technology.

TPACK refers to the synthesized form of knowledge for the purpose of integrating educational technology into classroom practices (Chai et al., 2013). Originally given the acronym of TPCK, the acronym has recently been changed to TPACK for the ease of pronunciation (see Thompson & Mishra, 2007). TPACK has been described as situated, complex, multifaceted, integrative and/or transformative knowledge (Angeli & Valanides, 2009; Koehler & Mishra, 2009).

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 (Pedagogical Content Knowledge), TCK (Technological Content Knowledge), TPK (Technological Pedagogical Knowledge), and TPACK (Technological Pedagogical Content Knowledge), consist of the interactions between and among these bodies of knowledge (Koehler & Mishra, 2005; Koehler & Mishra, 2009). Among all components, TPACK component is the basis of the framework since it is found in the interplay of all the components.

2.2 The measuring of TPACK

Only of questionnaire survey measurement of TPACK is being discussed in this section, considering the methodological base of this article.

2.2.1 Attempts of measuring TPACK

As Voogt et al. (2012) reviewed, the seven components of the TPACK framework were represented as sub-scales. Efforts to construct surveys for this purpose began with Koehler and Mishra (2005). They constructed a 14 items survey to chart 12 graduate students' developmental trajectories as these teachers were engaged in designing ICT integrated lesson. One other study on the measurement of TPACK was carried out by Archambault and Crippen (2009), focusing on examining teachers' knowledge with respect to each one of the components of the TPACK framework. Another study on developing a TPACK survey was carried out by Sahin (2011), including seven subscales based on the seven components of TPACK framework. Schmidt et al. (2009) constructed the Survey of pre-service Teachers' Knowledge of Teaching and Technology with 124 pre-service teachers in the USA which consisted of 58 items that measures all the seven constructs of TPACK. TPACK surveys have also been administered also with Asian teachers. Chai and his colleagues 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, 2010b; Chai, Koh, Tsai, & Tan, 2011). For instance, Chai et al. (2011) were able to uncover five of the seven TPACK constructs, which were a better model fit as compared with several extant studies of TPACK surveys.

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

2.2.2 Challenges of construct validation

Several studies reported difficulties and challenges with TPACK construct validation. Especially, the 7-component TPACK framework could not be reproduced through EFA (Archambault & Barnett, 2010; Koh et al., 2010), claiming that the boundaries between the components are fuzzy (Graham, 2011; also see Voogt et al., 2012). For instance, Archambault and Barnett's (2010) exploratory factor analysis of a TPACK survey for online teaching found that the items for CK, PK and PCK loaded as one factor whereas the items for TPK, TCK, and TPCK loaded as another. Lee and Tsai (2010) were able to isolate the factors of TK, TPK, TCK and TPACK, but found that the PK and PCK items had loaded as a factor.

While Chai and his colleagues' effort to validate the TPACK instrument is laudable, the only validation that involves both EFA and CFA (Chai et al., 2011) uses the same participants. This may suffer in terms of research rigor instrument validation. Chai and colleagues subsequent studies reported solely CFA, including a recent study for pre-service teachers from China, Taiwan and Singapore (Chai et al., 2013). To ensure that the TPACK survey possess high quality of reliability and validity, this study builds-on Chai and his colleagues work to validate a Chinese version of TPACK survey for China pre-service teachers. The validation of this survey would then allow China teacher education institutes to surface their pre-service teachers' TPACK profile for the planning, implementation and assessment of the effectiveness of pre-service teacher preparation.

2.3 Purpose of the present study

Taken into account the challenges of construct validation of previous study and necessities of a Chinese version of TPACK to fit in with Chinese culture and educational settings, the purpose of the present study is to develop and validate a measure to empirically measure and describe pre-service teachers technological pedagogical content knowledge. To serve this purpose, the present article contains three distinct phases: (1) to develop an item pool on pre-service teachers technological pedagogical content knowledge and explore its factor structure; (2) to confirm and refine the received instrument; (3) to explore the correlations between different factors of the scale.

3. Methodology

3.1 Data source

The CTPCK items were originally from TPACK-ML survey in Singapore (Chai et al., 2011). In their study, the survey instruments developed by Schmidt et al (2009) and Koh et al. (2010) were selected as it could be adapted to analyze the CK of Singapore teachers with respect to the variation of their teaching subjects. Chai and his colleagues created 13 items to substitute the PK items in Schmidt et al.'s (2009) survey to better address the pedagogical emphasis of our ICT course. TKW (technological knowledge about the World Wide Web) was added to development of the instrument of the present study, considering the crucial importance of Internet for students and teachers. The original English version instrument used in Singaporean settings was translated into Chinese by one of the authors then rechecked by 3 scholars in educational sciences. All the four participants had excellent bilingual competence of both languages.

The final instrument therefore comprised 42 questions that were measured on a 7-point Likert scale where: (1) Strongly disagree (2) Disagree (3) Slightly Disagree (4) Neither Agree Nor Disagree (5) Slightly Agree (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 9 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. In regard to family location of the participants, 232 (53.2%) were from rural regions and 192 (44%) from urban regions. Studying years of students were asked. 179 (41.1%) of respondents were freshmen, 86 (19.7%) were sophomores, 113 (25.9%) were juniors, and the reminder 58 (13.3%) were seniors. As to majors the participants taking, 7 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%).

3.3 Analysis

To develop and evaluate the CTPCK, we conducted factor analyses. First, exploratory factor analyses (principal axis factoring) using SPSS were carried out on the results of a first stratified randomly selected subsample (n = 229) to identify clusters in the scales concerning the technological pedagogical content knowledge. Second, in order to examine the stability of the exploratory factor structure, after removing items with low factor loadings and cross loadings, confirmatory factor analyses (CFA) was performed on the data of the second stratified randomly selected subsample (n = 207), using AMOS 18, following the procedures recommended by Hair, Black, Babin, and Anderson (2010). Next, the results of the confirmatory factor analyses were reexamined on the data of the first subsample. Last, the reliability of the scores of the final version of the CTPCK was determined.

4. Results

4.1 Exploratory factor analyses

The results of a first stratified random subsample (n = 229) were used to carry out exploratory factor analyses, which helped identify a number of latent factors of pre-service teachers' technological pedagogical content knowledge. In order to reset the correlations between factors and to help interpret the factors, Varimax Oblimin rotation was used. The number of factors, the lower limit of the item eigenvalue was taken as 1.00 to determine the number of factors. Moreover, the factor load lower limit of each item was taken as .40 (DeVellis, 2003; Field, 2005; Netemeyer, Bearden, & Sharma, 2003), and the lower limit of the differences of each item within the factors was taken as .10 (Coombs & Schroeder, 1988; R. B. Kline, 2005; Tabachnick & Fidell, 1996). The KMO sample competency was measured in order to test the validity of the size of the sample statistically. The KMO value, which can have a value between 0 and 1,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 higher than .9 (Field, 2005). As a result of that process, the KMO value was calculated as .952. Since the calculated KMO value was higher than .9, it was considered that the size of the sample was highly acceptable.

Based on the results, the 8-factor solution accounted for the 79.278% of the variance (TPCK = 49.277, PCK = 9.749, CK = 5.700, PK = 4.396; TKW = 2.908, TK = 2.572, TCK = 2.238,TPK = 2.296). The total variance explained is 79.287%. The value of variance above 40% is claimed to be sufficient for social science studies (Gorsuch, 1983; Netemeyer et al., 2003). Therefore, the total variance explained found over 50% in this study could be said to be within the acceptable limits.

4.2 Confirmatory Factor Analyses

Confirmatory factor analysis was conducted to confirm the factor structure of the scale, based on the data from the second stratified random subsample (n = 207). In the study, Confirmatory Factor Analysis (CFA) was conducted with AMOS program in order to determine whether variable groups contributing to the factor in the 8-dimension CTPACK Scale as a result of the exploratory factor analysis were efficiently represented by these factors or not.

In evaluating the model fit, we supplement the model chi-square statistic with both absolute and incremental fit indices (Bentler & Bonnett, 1980; Hu & Bentler, 1998, 1999). Absolute fit indices evaluate how well an a priori model reproduces the sample data. We report the 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). The standardized root mean square residual (SRMR) is reported for which a value of .08 or lower indicates a good fit (Hu & Bentler, 1999). Incremental fit indexes 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 a baseline model. We report the comparative fit index (CFI), the Tucker–Lewis index (TLI), and the goodness-of-fit index (GFI), which have cutoff values close to .95 (Hu & Bentler, 1999). After examination of parameter estimates, fit indexes, and residuals, model modifications are conducted to the original hypothesized model to have better fitting or a more parsimonious model (Schreiber et al., 2006).

The result of the confirmative factor analysis revealed moderate model fit (χ^2 = 964.084 [df = 594, p < .001], GFI= .804, CFI = .939, TLI = .931, SRMR = .051, RMSEA = .054 with a 90% interval of .048 to .060).

4.3 Reliability of the CTPCK Scores

The reliability of the scores of the CTPCK scale was determined by 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 scores of the scales had acceptable reliability coefficients (see Table 1): a = .90 (CK), a = .93 (PK), a = .95 (PCK), a = .93 (TK), a = .85 (TKW), a = .92 (TPK), a = .91 (TCK), and a = .91 (TPCK).

Table 1 Description statistics and reliability coefficient for each subscale

Subscale	Number of items	Mean	SD	alpha
CK	4	3.99	1.19	.90
PK	5	4.62	1.10	.93
PCK	8	4.55	1.11	.95
TK	4	4.55	1.25	.93
TKW	3	5.11	1.32	.85
TPK	5	4.82	1.06	.92
TCK	4	4.48	1.14	.91
TPCK	4	4.45	1.13	.91

4.4 The Description and Analysis of TPACK

In this part, results concerning the perceptions of pre-service teachers' technological pedagogical content knowledge are presented. Table 2 also shows the mean scores of the 8 subscales, varied from 3.99 (SD = 1.19) for CK to 5.11 (SD = 1.32) for TKW. These results suggested that pre-service teachers had high perceptions about technological knowledge related to the World Wide Web and relative low perceptions about content knowledge.

Finally, A first picture of the nature of the relationships between the research variables can be derived from the results of the bivariate correlation analysis (see Table 2). For the purpose of this study, the correlations with TPCK are of primary interest. The results suggest high interrelationships among different variables. For instance, PCK is significantly related to TPCK (r = .436). TCK presented the strongest correlation with TPCK (r = .726).

Table 2. Correlations coefficients for pairs of variables (N = 436)

	{1}CK	{2}PK	{3}PCK	{4}TK	{5}TKW	{6}TPK	{7}TCK
{1}CK							
{2}PK	.576**						
{3}PCK	.495**	.596**					
{4}TK	.446**	.504**	.441**				
{5}TKW	.202**	.431**	.350**	.524**			
{6}TPK	.384**	.596**	.554**	.673**	.656**		
{7}TCK	.436**	.540**	.397**	.722**	.581**	.690**	
{8}TPCK	.490**	.552**	.436**	.679**	.489**	.688**	.726**

5. Discussion

In the past decennia, much research focusing on TPACK has been generated. An interesting and remarkable development of research on TPACK is that researchers have turned their attention from a messy construct to a layered construct within TPACK framework as presented in Figure 1. However, researchers have commented that the boundaries of the TPACK constructs can be at times be rather vague, making it difficult to categorize instances of ICT integration (Cox & Graham, 2009; Koehler & Mishra, 2008; Lee & Tsai, 2010).

Based on our findings, pre-service teachers were able to distinguish the overlapping construct such as the TCK, PCK and TPK which were reported to be problematic in prior studies such as Lee and Tsai (20l0), Chai et al. (2010b) 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 needs to be given to the specific type of pedagogical approaches they intend to employ (Chai et al., 2010b).

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, individualized and inquiry-based learning activities (e.g., Lee & Tsai, 2005; Miller & Miller 2000; Tsai 2001). Hence force, in the present study, the breaking up of TK (of Mishra & Koehler, 2006) into two constructs of TK and TKW brings special concerns on "W" (the World Wide Web), in Chinese educational settings.

The reliability (Cronbach's alpha) coefficients for these factors were larger than .85, suggesting that these factors had highly sufficient reliability in assessing the pre-service teachers' TPCK.

6. Limitations and conclusions

The CTPCK has some limitations, which should be addressed in future research. A first limitation of our study was the limited sample of pre-service teachers considering the large population of their counterparts in China. Second, to develop the research instrument we randomly divided the original research sample in two subsamples. Hence, these two subsamples were not truly independent samples. In future research the modified model needs to be validated in an independent sample. Third, the appropriateness of the CTPCK should be assessed in a wider variety of contexts. Further refinement and evaluation of the CTPCK at other educational settings (e.g., school teachers) is needed. Finally, additional concurrent validity evidence is needed before the instrument is used extensively.

Building on the work of Lee and Tsai (2010), Chai et al., (2010a, 2011) and Koh et al. (2010), this study contributes to the extant study of TPACK through the creation of a survey with construct validity for all the seven TPACK constructs postulated by Mishra and Koehler (2006) and for one more construct related to knowledge about Internet. Both exploratory and confirmatory factor analyses verified reasonable and acceptable construction and validation of the scales. In conclusion, the acceptable internal consistency for the obtained dimensions and the strong correlation with related constructs support the notion that the CTPCK provides a useful measure to assess and describe pre-service teachers' technological pedagogical content knowledge.

References

Angeli, C. & Valanides, N. (2005). Preservice elementary teachers as information and communication technology designers: an instructional systems design model based on an expanded view of pedagogical content knowledge. *Journal of Computer Assisted Learning*, 21, 292-302.

Archambault, L., & Crippen, K. (2009). Examining TPACK among K-12 online distance educators in the United States. C*ontemporary Issues in Technology and Teacher Education*, 9(1), 71-88.

Barrbera, E. (2004). Quality in virtual education environments. *British Journal of Educational Technology,* 35, 13–20.

Becker, H. J. (2000). Findings from the teaching, learning and computing survey: is Larry Cuban right? *Educational Policy Analysis Archives*, 8, 1-32.

Bentler, P. M., & Bonnett, D. g. (1980). Significance tests and goodness of fit in the analysisof covariance structures. *Psychological Bulletin, 88,* 588-606.

Browne, M. W., & Cudeck, R. (1992). Alternative ways of assessing model fit. *Sociological Methods & Research, 21,* 230-258.

Chai, C. S., Koh, J. H. L., & Tsai, C. C. (2010a). Facilitating preservice teachers' development of technological, pedagogical, and content knowledge (TPACK). *Educational Technology & Society*, 13(4), 63-73.

Chai, C. S., Koh, J. H. L., & Tsai, C. C. (2010b). Exploring the Factor Structure of the Constructs of Technological, Pedagogical, Content Knowledge (TPACK). *Asia-Pacific Education Researcher* 20(3), 595-603.

Chai, C. S., Koh, J. H. L., Tsai, C. C., & Tan, L. L. W. (2011). Modeling primary school pre-service teachers' Technological Pedagogical Content Knowledge (TPACK) for meaningful learning with information and communication technology (ICT). *Computer and Education*, 57,1184-1193.

Chai, C. S., Koh, J. H. L., & Tsai, C. C. (2013). A Review of Technological Pedagogical Content Knowledge. *Educational Technology & Society*, 16(2), 31-51.

Cox, S. & Graham, C. R. (2009) Diagramming TPACK in practice: using and elaborated model of the TPACK framework to analyze and depict teacher knowledge. *TechTrends*, 53, 60-69.

Fan, X., & Thompson, B. (2001). Confidence intervals about score reliability coefficients, please: an ePM guidelines editorial. *Educational and Psychological Measurement, 61*, 517-531.

Gorsuch, R. L. (1983). Factor analysis. Hillsdale, NJ: Lawrence Erlbaum.

Hair, J. F .. Black, W. C., Babin, B. J. & Anderson, R. E. (20 1 0). Multivariate data analysis: A global perspective. (7th ed.). Upper Saddle River, NJ: Pearson.

Henson, R. K. (2001). Understanding internal consistency reliability estimates: a conceptual primer on coefficient alpha. *Measurement and Evaluation in Counseling and Development, 34*, 177-189.

Hu, L., & Bentler, P. M. (1998). Fit indices in covariance structural equation modeling: Sensitivity to underparameterized model misspecification. *Psychological Methods, 3,* 424-453.

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6*, 1-55.

Keating, T., & Evans, E. (2001). Three computers in the back of the classroom: preservice teachers' conceptions of technology integration. In J. Price, et al. (Eds.), *Proceedings of society for information technology & teacher education international conference 2001* (pp. 1671-1676). Chesapeake, VA: AACE.

Koehler, M. J. & Mishra, P. (2005) What happens when teachers design educational technology? The development of technological pedagogical content knowledge. *Journal of Educational Computing Research,* 32, 131-152.

Koehler, M. J., & Mishra, P. (2009). What Is Technological Pedagogical Content Knowledge?. *Contemporary Issues in Technology and Teacher Education (CITE Journal),* 9(1), 60-70.

Koh, J. H. L., Chai, C. S., & Tsai, C. C. (2010). Examining the technology pedagogical content knowledge of Singapore pre-service teachers with a large-scale survey. *Journal of Computer Assisted Learning*, 26(6), 563-573.

Lee, M. -H., & Tsai, C. -C. (2005). Exploring high school students' and teachers' preferences toward the constructivist internet-based learning environments in Taiwan. *Educational Studies*, 31, 149-167.

Loo, R. (2001). Motivational orientations toward work: an evaluation of the Work Preference Inventory (Student form). *Measurement and Evaluation in Counseling and Development, 33*, 222-233.

Miller, S. M., & Miller, K. L. (2000). Theoretical and practical considerations in the design of web-based instruction. In B. Abbey (Ed.), *Instructional and cognitive impacts of web-based instruction* (pp. 156–177). Hershey, PA: Idea Group Publishing.

Netemeyer, R., Bearden, W., & Sharma, S. (2003). Scaling procedures. Thousand Oaks, CA: Sage Publications.

Pierson, M.E. (2001). Technology integration practice as a function of pedagogical expertise. *Journal of Research on Computing in Education*, 33, 413-430.

Sahin, I. (2011). Development of survey of technological pedagogical and content knowledge (TPACK). *The Turkish Online Journal of Educational Technology*, 10(1), 97-105.

Schmidt, D. A., Baran, E., Thompson, A. D., Koehler, M. J., Mishra, P., & Shin, T. (2009). Technological pedagogical content knowledge (TPACK): the development and validation of an assessment instrument for preservice teachers. *Journal of Research on Technology in Education*, 42(2), 123-149.

Schreiber, J. B, Nora, a., Stage, F. K., Barlow, e. a., & King, J. (2006). Reporting structural equation modeling and confirmatory factor analysis: a review. *Journal of Educational Research, 99*, 323-337.

Shulman, L. S. (1986). Those who understand: knowledge growth in teaching. *Educational Researcher*, 15, 4-14.

Thompson, A. & Mishra, P. (2007). Breaking news: TPCK becomes TPACK! *Journal of Computing in Teacher Education*, 24, 38-39.

Tsai, C. -C. (2001). The interpretation construction design model for teaching science and its applications to internet-based instruction in Taiwan. *International Journal of Educational Development*, 21, 401-415.

Wallace, R. M. (2004). A framework for understanding teaching with the internet. *American Education Research Journal*, 41, 447–488.

Voogt, J., Fisser, P., Pareja, Roblin, N., Tondeur, J., & van Braak, J. (2013). Technological pedagogical content knowledge – a review of the literature. Journal of Computer Assisted Learning, 29(2)109-121.

Zhan, Y., & Ren, Y. Q. (2011). Improving TPACK of Mathematics pre-service teachers: an experimental research [培养数学专业师范生 TPACK 的实验研究]. *China Educational Technology* [中国电化教育],10, 15-23.