Effects of the TPACK Levels of University Teachers on the Use of Online Teaching Technical Tools

https://doi.org/10.3991/ijet.v17i20.35135

Yaping Tao(✉), Jianhua Ma
School of Traffic Engineering, Huanghe Jiaotong University, Jiaozuo, China
2016101903@zjtu.edu.cn

Abstract—The effects of technological pedagogical content knowledge (TPACK) on teachers' use of online teaching technical tools are analyzed through a case study based on 297 civil engineering teachers in 7 universities of China. Results show that the overall Cronbach's α is 0.868, Kaiser–Meyer–Olkin test (KMO) is 0.781, and the corresponding *P* value is 0.000, indicating the high reliability and validity of the study. The content knowledge (CK), technological knowledge (TK), and TPACK of civil engineering teachers in universities have significantly positive effects on their use of online teaching technical tools. Conclusions can provide important references to expand the research scope and content of TPACK, promote the professional development of civil engineering teachers in universities, and help them enrich information knowledge structure.

Keywords—TPACK level, use of online teaching technical tools, questionnaire survey, regression analysis

1 Introduction

The emergence of new technologies, such as artificial intelligence, virtual reality, and quantum information, symbolizes the combination of new industrial age. An emergency shutdown of face-to-face teaching in schools has taken place around the world due to the unexpected COVID-19 outbreak in China. Online learning has become a mainstream learning mode during the COVID-19 outbreak. The Ministry of Education of China has been organizing and constructing online course resources and strengthening technological support services since 2020. The COVID-19 outbreak promotes the "Internet + education" project indirectly, and teaching modernization is driven by educational informationization. Such sudden changes in daily teaching mode bring great challenges to the information literacy and knowledge capability of university teachers. Many teachers know nothing about the production and management of online course materials. They encounter many difficulties in stimulating students' interests in remote learning and assuring the effectiveness of online learning even though they can complete the preparation of teaching content. The information literacy of university teachers generally has been improved after training on their information technological application ability over years. However, many teachers still find it difficult to make quick changes in a short period upon failure of accessing to the original teaching mode during the COVID-19 outbreak. Meanwhile, online teaching platform is still used in daily teaching as a learning assistant platform.

Rapid and continuous innovation and progresses occur in the field of technology, information, and knowledge transfer in the 21st century. The teaching process may be changed fundamentally by the increasing popularity of digital technology and network media. However, research on the applications of technologies to teaching find that teachers often lack the successful integration of technology into teaching knowledge. In practice, teachers are key elements in knowledge transfer and are organizers of the whole teaching activity. Teachers play important roles in realizing a high-efficiency and qualified teaching process. Teachers must set up the philosophy of lifelong learning, update their knowledge level timely, and improve their professional teaching ability because they are responsible for the training of social talents in the future. With the increasing popularity of digital technology and network media, the educational pattern is updating continuously. Changes occur in the representation mode of teaching content and teacher–student interaction mode. Discussions on education cannot ignore the existence of technologies. Specifically, information technology (IT) has considerable values and significance to knowledge innovation and knowledge accumulation in the higher education field, realizing interdisciplinary knowledge reconstruction. In the current background that IT has embedded completely into the education industry, technology has become a knowledge content of teachers that is as important as CK and TK. Technological pedagogical content knowledge (TPACK) has important influences on the professional development of teachers. For higher engineering education, the TPACK framework is not only the essential knowledge reserve condition for teachers to carry out teaching activities but also an important reference for the professional development of engineering teachers.

2 Theoretical basis and hypotheses development

2.1 Theoretical basis

The development of TPACK theory has attracted the attentions of educators in the application of CK to teaching activities. Shulman, L. S. [1], a famous educational psychologist, put forward that educators have to master pedagogical content knowledge (PCK) formed by the crossing of CK and pedagogical knowledge (PK) in addition to CK and PK. With the progresses of science and technology, people become increasingly aware of the importance of IT to education and teaching. Technological means are introduced into teaching activities continuously, which propose new requirements on teachers' ability. Mishra, P et al. [2], from the Michigan State University, added technological knowledge (TK) into the PCK theoretical framework and proposed TPACK for the first time in 2005. TPACK is the basis to optimize teaching activities on the basis of technologies, and it provides a deep integration of technologies, pedagogics, and CK innovatively. The TPACK model in the emerging knowledge form, which surpasses technologies, pedagogics, and CK, has attracted extensive academic attentions after it is proposed. It is called the new professional knowledge structure of teachers in the information age. Schmidt, D. A et al. [3] performed a systematic study on TPACK (Figure 1). It is composed of seven aspects, namely, CK, PK, TK, PCK, technological content knowledge (TCK), technological pedagogical knowledge (TPK), and TPACK.

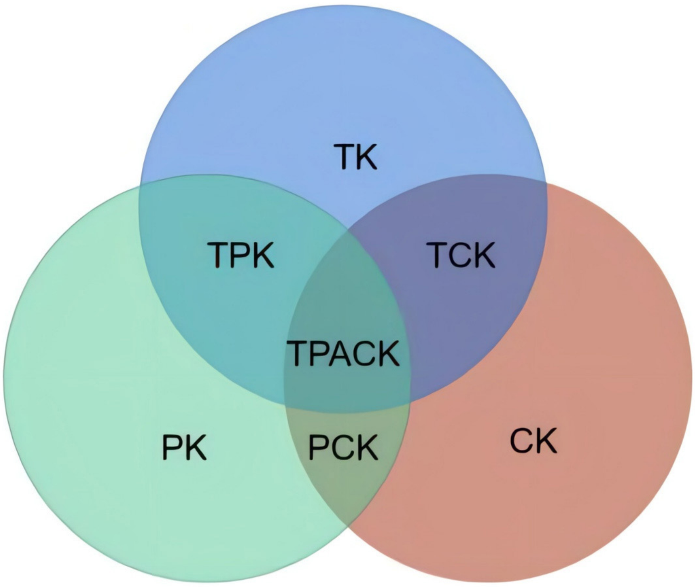

Fig. 1. TPACK theoretical model

2.2 Hypotheses development

Many scholars have explored the professional development and technology-integrated educational teaching of teachers around TPACK since it is proposed. Brantley-Dias, L et al. [4] believed that the TPACK framework has become a popular structure to check the knowledge type of teachers to realize technological integration. He made a critical review on the TPACK structure and discussed the development, verification, usefulness, application, and appropriateness of TPACK to interpret teachers' cognition needed for effective technological integration. Niess, M. L [5] pointed out that TPACK provides a dynamic framework to describe the essential knowledge of teachers in the design, implementation, and assessment of technological courses and teaching. He also reviewed the empirical progress in the TPACK survey. Pamuk, S et al. [6] explored the essence of relationships among TPACK components. The level-2 knowledge bases (TPK, TCK, and PCK) had stronger influences on the prediction of TPACK development than the core ones. Niess, M. L et al. [7] provided references for mathematics teachers to reflect the TPACK standards. A TPACK development model for mathematics teachers was developed, which could guide teachers, researchers, teacher educators, professional development counselors, and school managers to formulate and evaluate professional development activities, mathematics education plans, and school mathematics plans. Graham, C. R et al. [8] discussed the influences of TPACK on the learning of students. The ability of students in using the basic principles on the basis of specific CK and ordinary TK was improved significantly, but their use of basic principles related with ordinary TK was kept constant. Bustamante, C et al. [9] studied the professional development case of Web 2.0 for Spanish teachers and found that the TPACK model can improve the teaching levels of teachers. Phillips, M [10] explored the eight-month case where 10 teachers from a middle school in Australia participated in and found that the TPACK formulation is influenced by identity development and practice process. Thomas, T et al. [11] deemed that a challenge is to transform the preparation plans of teachers into completely realized TPACK environments and determine essential learning opportunities and supports to stimulate leaders and teachers of colleges to accept the reform process comprehensively. Jang, S. J et al. [12] investigated the TPACK of science teachers in middle schools from the perspectives of gender and teaching experiences. Male science teachers reported significantly higher evaluation of TK than female ones. Gender and teaching experiences are two influencing factors of the TPACK of science teachers in middle schools. Jang, S. J et al. [13] discussed the relationship between the TPACK of mathematics and science teachers from primary schools in Taiwan and the current interactive whiteboards. The results demonstrated that significant differences in TPACK exist between teachers who used and did not use IWBs. The TPACK of teachers with different teaching experiences is significantly different. Saudelli, M. G et al. [14] analyzed the self-efficacy belief of primary school teachers and their attitude toward mobile technology-strengthened teaching. The results revealed that teachers' attitude toward iPad technological integration formed their basis of teaching mode. PK and the teaching experiences of teachers influenced their decision making in mobile technological integration more than TCK and CK. All teachers found stronger connection and consciousness with TPACK components. Koh, J. H. L et al. [15] investigated the cognition of 354 student teachers in constructivism-oriented TK, PK, and CK. The results showed that improving their confidence in constructivism technological integration is conducive when teachers are developing the middle form of TK, PK, and CK. Valtonen, T et al. [16] carried out a case study of pre-service teachers (N = 86) in Finland University. The results provided an important perspective for pre-service teachers to develop TPACK and disclosed important role of PK. Chai, C. S et al. [17] believed that TPACK theory is divided into a seven-element structure to describe teachers' integration of information and communication technology (ICT) in teaching. He found that PK has direct influences on TPACK in the beginning of a course. Yeh, Y. F et al. [18] investigated 40 teachers who have different disciplinary backgrounds, years of teaching experiences, and relevant rewards and found that the TPACK-P of teachers must accumulate context and dynamic experiences in the implementation process of ICT during practical teaching activities. Koh, J. H. L et al. [19] investigated the team cooperation of 27 primary school teachers in Singapore in speech design when including the student-centered ICT into the school courses. He found that teachers used seven design frameworks in the ICT course design and key attentions were paid to PCK, TPACK, and design knowledge. Maeng, J. L et al. [20] had pre-service teachers assuming the responsibility of technical supportive inquiry teaching and supported TPACK development. According to regression analysis, Chai, C. S et al. [21] demonstrated that TK, PK, and CK are significant predictive factors of the TPACK of pre-service teachers, and PK is the primary influencing factor. Sahin, I [22] investigated TPACK in Turkish and English to pre-service teachers engaged in

English education. The results showed that TPACK survey is an effective and reliable measure. Mishra, P et al. [23] believed that educators must readjust the purposes of tools and integrate them into teaching. They need a kind of specific knowledge, which is called TPACK. Nuangchalerm P [24] carried out a questionnaire survey and teaching plan analysis on the explosive TPACK of seven pre-service teachers in Thailand during a one-year school internship and found that they have relatively high TPACK levels. Akturk, A. O et al. [25] analyzed the relationship among the TPACK levels of teachers and the self-efficacy and academic performances of students. The results revealed that the academic, social, and emotional self-efficacies of students and the TPACK levels of teachers interpreted 12% of students' academic achievements. Academic self-efficiency is the most important variable that influences the overall academic performances of students. The teaching process implemented by Durdu, L et al. [26] has a positive effect on the TPACK development of pre-service teachers. Significant differences in TK, TCK, TPK, and TPACK can be observed before and after the course implementation. Zidoun, Y et al. [27] used a thematic synthesis methodology to present a framework for mobile devices integration in learning. The five-axis framework consists of enriching the TPACK framework in order to more precisely address mobile learning by covering the following parts: pedagogy, content, mobile technology, learning environment and learner's profile.

Studies on the influencing factors of the TPACK levels of teachers at home and abroad are rare. Quantitative research is the major method. Existing studies mainly focus on internal influencing factors but pay few attentions to external ones. In-service teachers or pre-service teachers in the basic education stage are major research objects. University teachers are hardly involved in these studies. Based on previous results, the current research attempts to explore the influencing factors of the TPACK levels of civil engineering teachers in universities in the new engineering background. Some specific suggestions are proposed according to research conclusions. Based on the above literature review, seven research hypotheses are presented as follows:

H1: CK can prompt teachers to use online teaching technical tools.
H2: PK can prompt teachers to use online teaching technical tools.
H3: TK can prompt teachers to use online teaching technical tools.
H4: PCK can prompt teachers to use online teaching technical tools.
H5: TCK can prompt teachers to use online teaching technical tools.
H6: TPK can prompt teachers to use online teaching technical tools.
H7: TPACK can prompt teachers to use online teaching technical tools.

3 Methodology

3.1 Questionnaire design

A questionnaire survey using the "Questionnaire on the Use of TPACK and Hybrid Teaching Technological Tools by Civil Engineering Teachers in Chinese Universities" was carried out. This questionnaire was composed of three parts. Part I determined the gender, education background, title, and age of respondents. Part II explored the

TPACK levels of respondents and was mainly revised from the TPACK–EFL scale developed by Baser, D et al. [28]. The TPACK–EFL scale involved seven factors and was revised in this study. A total 29 questions were designed, including 4, 5, 4, 4, 4, 3, and 5 questions for each factor. Part III investigated respondents' use of hybrid teaching technological tools. The questionnaire of Vannatta, R. A et al. [29] was used, and the use of online teaching technical tools (WTU) was tested by five questions. Two scales of the questionnaire used the five-point Likert scale statistical methods. Respondents were asked to grade agreements to the opinions stated in the scales (completely disagree = 1, disagree = 2, uncertain = 3, agree = 4, and completely agree = 5).

3.2 Respondents

Respondents were collected randomly from civil engineering teachers in seven universities in Shaanxi Province. Questionnaire survey was the major method. A total of 384 questionnaires were sent by combining field and online methods. Finally, 364 were collected, including 297 valid ones, showing a recovery rate of 81.59%. Subsequently, a statistical analysis on questionnaire survey data was carried out using EXCEL and SPSS26.0. The basic descriptive statistical results are listed in Table 1.

Table 1. Descriptive statistical results of respondents

Gender	Male	239	80.47%
	Female	58	19.53%
Education	Bachelor	38	12.79%
	Master's	100	33.67%
	PhD	159	53.54%
Age	20–25	40	13.47%
	26–30	67	22.56%
	30–35	33	11.11%
	36–40	40	13.47%
	40–45	84	28.28%
	> 45	33	11.11%
Title	Teaching assistant	15	5.05%
	Lecturer	166	55.89%
	Associate professor	102	34.34%
	Professor	14	4.71%

Table 1 shows that the civil engineering department has more male teachers than female teachers, accounting for 80.47. Thus, male teachers take the dominant role. This result basically reflects the basic gender distribution of civil engineering teachers in China. The proportion of males is higher than that of females due to the character of the industry. Such gender distribution still exists in universities even though it is not the engineering frontline. The proportion of PhD teachers accounts for 53.54%, indicating the high education background of civil engineering teachers. They may more likely be highly interested in using novel online teaching tools and are more likely to develop their own online courses. Hence, the frequency of online information-based teaching tool use is high. Young teachers (<45) account for 88.88% of the total respondents, suggesting that middle-aged and young teachers are the major forces in science teacher teams in universities. Universities are introducing new talents continuously during development. Associate professors and professors account for 39%, which is relatively consistent with title structure in most universities at present. Therefore, the investigated universities have good strength and high teacher quality, and the respondents generally have good scientific research and teaching abilities.

4 Results analysis and discussion

4.1 Reliability and validity test

First, the primary aim is to analyze reliability for checking the internal consistency of questions in the questionnaire. In general, it is viewed as high reliability if Cronbach's α is higher than 0.7. In this study, the reliability of the designed questionnaire was tested by the reliability analysis function in SPSS software (26.0). A statistical analysis on Cronbach's α was carried out (Table 2).

Table 2. Reliability results

Variable Name	Number of Questions	Cronbach's α	Cronbach's α
CK	4	0.806	0.868
PK	5	0.868	
TK	4	0.792	
PCK	4	0.747	
TCK	4	0.909	
TPK	3	0.811	
TPACK	5	0.877	
WTU	5	0.871	

Table 2 presents that the overall Cronbach's α of the questionnaire is 0.868 (> 0.8). Meanwhile, the Cronbach's α of all variables is higher than 0.7, indicating the high reliability of the questionnaire.

Validity analysis refers to the analysis on the scale expression accuracy of measurement indicators.

Table 3. Kaiser–Meyer–Olkin (KMO) and Bartlett's tests

KMO		0.781
Bartlett sphericity test	Approximate chi-square	3642.489
	Degree of freedom	276
	Significance	0.000

Table 3 shows that KMO is 0.781, indicating that the factor analysis effect is generally good. P value is 0.000, suggesting that the independent hypotheses of variables (questions) are rejected and a strong correlation exists among variables (questions).

4.2 Regression analysis

Table 4. Linear regression results

Variable	Normalization Coefficient	*T* value	*P* value
Constant	0.4456	4.907	0.000
CK	0.103	−1.711	0.088*
PK	0.085	1.406	0.161
TK	0.174	3.082	0.002***
PCK	−0.015	−0.246	0.806
TCK	0.047	0.738	0.461
TPK	0.015	0.248	0.805
TPACK	0.271	4.660	0.000***

Notes: *refers to significance under the 1% level. ***refers to significance under 10% level.

The following are discussed in Table 4.

(1) H1 is true. CK can significantly prompt teachers to use online teaching technical tools efficiently. This result fully interprets that the design of the online information-based teaching ability training model should depend on the characteristics of CK, add content related to the subject appropriately, and facilitate the effective integration of IT in subject teaching. Teachers who have more CK are more liable to use online teaching technical tools. Technology can provide CK further representation forms and facilitate its development and changes. Different CK tools require different technical representations. Teachers must understand the role of technologies in subject content, which can help them choose the best technological method.
(2) H2 is false. PK cannot prompt teachers to use online teaching technical tools efficiently. Possible reasons are analyzed in the following. This study focuses on civil engineering teachers in universities who mainly learn professional knowledge in PhD programs but learn few PK. At present, university students in China mainly learn Pedagogy and Educational Psychology when they are preparing for the University Teacher Certificate examination. They have no more learning of teaching method. Another possible reason is that many universities emphasize on the training of teachers' scientific research ability but ignore the training of their PK. Hence, civil engineering teachers have no more enthusiasm in using online teaching technical tools.
(3) H3 is true. TK can significantly prompt teachers to use online teaching technical tools efficiently. Given that most university teachers in the questionnaire survey have good learning ability, they may take the initiative to learn TK after

information-based teaching competition in universities. Teachers change the original teaching ideas and teaching modes by introducing new technologies to improve the application effects of teaching strategies. The knowledge requires teachers to overcome restraints in the original functions of technologies, use TK flexibly according to teaching needs, and facilitate them to use online teaching technical tools flexibly. They can also master TK by analyzing teaching cases, understand the production processes of teaching resources, and lay foundations for the training of information-based teaching design ability.

(4) H4 is false. PCK cannot prompt teachers to use online teaching technical tools efficiently. PCK is formed by the effective integration of CK and PK. PCK means that teachers reorganize and arrange CK using an appropriate teaching method in the real teaching environment, so that students can understand and master it easily. This study involves civil engineering teachers, and civil engineering focuses on operational ability training, whereas online learning emphasizes on knowledge transfer. Teachers cannot provide the expected help using online teaching tools, thereby inspiring university teachers to pay attention to the efficient integration of relevant online teaching tools and CK.

(5) H5 is false. TCK cannot prompt teachers to use online teaching technical tools efficiently. TCK is the product of interaction between TK and CK. Given that online teaching technology becomes increasingly complicated, university teachers easily feel fatigue upon multiple selection and they must understand the role of technologies in subject content to choose the best technological method. However, teachers cannot develop scientific knowledge for technological integration well because their assessment emphasizes on scientific research.

(6) H6 is false. TPK cannot prompt teachers to use online teaching technical tools efficiently. TPK is formed by combining TK and PK. It requires university teachers to change the original teaching ideas and teaching modes by introducing new technologies to improve the application effects of teaching strategies. University teachers emphasize on scientific research assessment in recent years but have not conducted further practice studies in the integration of PK and IT. TPK requires teachers to overcome restraints in the original functions of technologies and use TK flexibly according to teaching needs. Hence, university teachers do not study TPK teaching deeply and effectively.

(7) H7 is true. TPACK can significantly prompt teachers to use online teaching technical tools efficiently. TPACK is formed by combining CK, PK, and TK, which are keys for university teachers to teach knowledge during scientific research. They must be further integrated scientifically by universities. Teachers of different disciplines in universities should choose a reasonable teaching method according to the subject content and formulate the implementation scheme of teaching design using appropriate online teaching technological means to help students construct significant knowledge. Doing so can help realize the optimal teaching effect and facilitate teachers to use online teaching technical tools efficiently.

4.3 Discussions

In this study, whether TPACK can prompt teachers to use online teaching tools efficiently is determined using the questionnaire survey method. Three pairs of path relations with statistical significance are discovered in a regression analysis. The findings reveal that CK, TK, and TPACK can prompt teachers to use online teaching tools efficiently. Face-to-face teaching technological tools are used mostly by civil engineering teachers in universities during the COVID-19 outbreak and normalized control, including computer and projection system, interactive white board, and multimedia application technologies. Hence, TK is the key to influence their use of online teaching tools. With the improvement of the education backgrounds of teacher teams, teacher teams in universities have solid CK, rich PK, and rich teaching experiences at present. Moreover, university teachers organize teaching content and produce exhibition materials, such as excellent courseware and animation videos, using multimedia technologies and network resources. Meanwhile, they output and manage course content to learners through the online platform. TPACK forced university teachers to use online teaching tools deeply during the COVID-19 outbreak.

5 Conclusions

Educational informationization is an important mean to optimize education structure, allocate education resource reasonably, and realize educational fairness. The use of IT and deep integration between IT and higher education-related courses is the key to improve higher education quality. Increasing the TPACK levels of university teachers is important in realizing deep integration between IT and the teaching of different subjects under the background of higher educational informationization. Based on the theoretical reference, how the TPACK of civil engineering in universities influences the use of online teaching technical tools is analyzed. The overall Cronbach's α is 0.868, KMO is 0.781, and the corresponding P value is 0.000, indicating the high reliability and validity of the study. The CK, TK, and TPACK of civil engineering teachers have significantly positive effects on their use of online teaching technical tools. However, PK, PCK, TCK, and TPK have no obvious positive effects yet. Further in-depth studies on planning the professional development policies of teachers, improving efficiency in knowledge skill training, strengthening their practical willingness of using information technological tools, and constructing an applicable TPACK model of teachers with clearer layers and richer connotations are needed in the future.

6 References

[1] Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. Educational Researcher, 15(2), 4–14. https://doi.org/10.2307/1175860

[2] Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. Teachers College Record, 108(6), 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

[3] Schmidt, D. A., Baran, E., Thompson, A. D., Mishra, P., Koehler, M. J., & Shin, T. S. (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. https://doi.org/10.1080/15391523.2009.10782544
[4] Brantley-Dias, L., & Ertmer, P. A. (2013). Goldilocks and TPACK: Is the construct 'just right?'. Journal of Research on Technology in Education, 46(2), 103–128. https://doi.org/10.1080/15391523.2013.10782615
[5] Niess, M. L. (2011). Investigating TPACK: Knowledge growth in teaching with technology. Journal of Educational Computing Research, 44(3), 299–317. https://doi.org/10.2190/EC.44.3.c
[6] Pamuk, S., Ergun, M., Cakir, R., Yilmaz, H. B., & Ayas, C. (2015). Exploring relationships among TPACK components and development of the TPACK instrument. Education and Information Technologies, 20(2), 241–263. https://doi.org/10.1007/s10639-013-9278-4
[7] Niess, M. L., Ronau, R. N., Shafer, K. G., Driskell, S. O., Harper, S. R., Johnston, C., … & Kersaint, G. (2009). Mathematics teacher TPACK standards and development model. Contemporary Issues in Technology and Teacher Education, 9(1), 4–24.
[8] Graham, C. R., Borup, J., & Smith, N. B. (2012). Using TPACK as a framework to understand teacher candidates' technology integration decisions. Journal of Computer Assisted Learning, 28(6), 530–546. https://doi.org/10.1111/j.1365-2729.2011.00472.x
[9] Bustamante, C. (2017). TPACK and teachers of Spanish: Development of a theory-based joint display in a mixed methods research case study. Journal of Mixed Methods Research. 13(2), 155868981771211. https://doi.org/10.1177/1558689817712119
[10] Phillips, M. (2016). Re-contextualising TPACK: Exploring teachers'(non-) use of digital technologies. Technology, Pedagogy and Education, 25(5), 555–571. https://doi.org/10.1080/1475939X.2015.1124803
[11] Thomas, T., Herring, M., Redmond, P., & Smaldino, S. (2013). Leading change and innovation in teacher preparation: A blueprint for developing TPACK ready teacher candidates. TechTrends, 57(5), 55–63. https://doi.org/10.1007/s11528-013-0692-7
[12] Jang, S. J., & Tsai, M. F. (2013). Exploring the TPACK of Taiwanese secondary school science teachers using a new contextualized TPACK model. Australasian Journal of Educational Technology, 29(4). https://doi.org/10.3402/meo.v18i0.22684
[13] Jang, S. J., & Tsai, M. F. (2012). Exploring the TPACK of Taiwanese elementary mathematics and science teachers with respect to use of interactive whiteboards. Computers & Education, 59(2), 327–338. https://doi.org/10.1016/j.compedu.2012.02.003
[14] Saudelli, M. G., & Ciampa, K. (2016). Exploring the role of TPACK and teacher self-efficacy: An ethnographic case study of three iPad language arts classes. Technology, Pedagogy and Education, 25(2), 227–247. https://doi.org/10.1080/1475939X.2014.979865
[15] Koh, J. H. L., Chai, C. S., & Tsai, C. C. (2014). Demographic factors, TPACK constructs, and teachers' perceptions of constructivist-oriented TPACK. Journal of Educational Technology & Society, 17(1), 185–196.
[16] Valtonen, T., Leppänen, U., Hyypiä, M., Sointu, E., Smits, A., & Tondeur, J. (2020). Fresh perspectives on TPACK: Pre-service teachers' own appraisal of their challenging and confident TPACK areas. Education and Information Technologies, 25(4), 2823–2842. https://doi.org/10.1007/s10639-019-10092-4
[17] 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). Computers & Education, 57(1), 1184–1193. https://doi.org/10.1016/j.compedu.2011.01.007

[18] Yeh, Y. F., Lin, T. C., Hsu, Y. S., Wu, H. K., & Hwang, F. K. (2015). Science teachers' proficiency levels and patterns of TPACK in a practical context. Journal of Science Education and Technology, 24(1), 78–90. https://doi.org/10.1007/s10956-014-9523-7
[19] Koh, J. H. L., & Chai, C. S. (2016). Seven design frames that teachers use when considering technological pedagogical content knowledge (TPACK). Computers & Education, 102, 244–257. https://doi.org/10.1016/j.compedu.2016.09.003
[20] Maeng, J. L., Mulvey, B. K., Smetana, L. K., & Bell, R. L. (2013). Preservice teachers' TPACK: Using technology to support inquiry instruction. Journal of Science Education and Technology, 22(6), 838–857. https://doi.org/10.1007/s10956-013-9434-z
[21] Chai, C. S., Koh, J. H. L., & Tsai, C. C. (2010). Facilitating preservice teachers' development of technological, pedagogical, and content knowledge (TPACK). Journal of Educational Technology & Society, 13(4), 63–73.
[22] Sahin, I. (2011). Development of survey of technological pedagogical and content knowledge (TPACK). Turkish Online Journal of Educational Technology-TOJET, 10(1), 97–105. https://doi.org/10.1080/00220485.2010.500565
[23] Mishra, P., & Koehler, M. (2009). Too cool for school? No way! Using the TPACK framework: You can have your hot tools and teach with them, too. Learning & Leading with Technology, 36(7), 14–18.
[24] Nuangchalerm, P. (2020). TPACK in ASEAN Perspectives: Case study on Thai pre-service teacher. International Journal of Evaluation and Research in Education, 9(4), 993–999. https://doi.org/10.11591/ijere.v9i4.20700
[25] Akturk, A. O., & Ozturk, H. S. (2019). Teachers' TPACK levels and students' self-efficacy as predictors of students' academic achievement. International Journal of Research in Education and Science, 5(1), 283–294.
[26] Durdu, L., & Dag, F. (2017). Pre-service teachers' TPACK development and conceptions through a TPACK-based course. Australian Journal of Teacher Education (Online), 42(11), 150–171. https://doi.org/10.14221/ajte.2017v42n11.10
[27] Zidoun, Y., Dehbi, R., Talea, M., & EI Arroum, F. (2019). Designing a theoretical integration framework for mobile learning. International Journal of Interactive Mobile Technologies (iJIM), 13(12), 152–170. https://doi.org/10.3991/ijim.v13i12.10841
[28] Baser, D., Kopcha, T. J., & Ozden, M. Y. (2016). Developing a technological pedagogical content knowledge (TPACK) assessment for preservice teachers learning to teach English as a foreign language. Computer Assisted Language Learning, 29(4), 749–764. https://doi.org/10.1080/09588221.2015.1047456
[29] Vannatta, R. A., & Nancy, F. (2004). Teacher dispositions as predictors of classroom technology use. Journal of Research on Technology in Education, 36(3), 253–271. https://doi.org/10.1080/15391523.2004.10782415

7 Authors

Yaping Tao, Master's degree, is a lecturer at School of Traffic Engineering, Huanghe Jiaotong University. Her research interests focus on Civil Engineering and Teaching Research. (email: 2016101903@zjtu.edu.cn).

Jianhua Ma, Master's degree, is a lecturer at School of Traffic Engineering, Huanghe Jiaotong University. His research interests focus on Civil Engineering and Teaching Research. (email: 2016010802@zjtu.edu.cn).

Article submitted 2022-08-03. Resubmitted 2022-09-16. Final acceptance 2022-09-17. Final version published as submitted by the authors.