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Chinese mathematics teachers' TPACK and attitudes toward ICT integration in the post-pandemic era

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Abstract
This study investigated primary mathematics teachers' technological, pedagogical, and content knowledge (TPACK) and attitudes towards information and communication technology (ICT) integration in mainland China during the post-pandemic period. Quantitative data were collected through a web-based self-determined questionnaire. Statistical analysis was performed using independent sample t-tests, and Mann-Whitney U tests to assess gender and teaching experience in years. Spearman's correlation test also examined the relationship between TPACK and teachers' attitudes towards ICT integration. The findings revealed that most mathematics teachers had adequate non-technology-related knowledge but lacked technology-related knowledge. However, they were willing to incorporate digital technologies in their teaching after experiencing large-scale online teaching. There was no significant gender or teaching grade differences in TPACK, but teaching experience positively correlated with TPACK. The study emphasizes the importance of assessing teachers' practical circumstances before introducing TPACK development programs. Finally, the implications for teachers, educators, and policymakers were discussed at the end of this paper.

Keywords: mathematics teachers, TPACK, attitudes, ICT integration, primary school

INTRODUCTION

Last a decade, many studies have investigated the relationship between TPACK and the integration of ICT in classroom teaching (Harris, 2016; Smith et al., 2016). Some researchers asserted that teachers' TPACK and their attitudes were at the core of the success of ICT integration in classroom teaching (Hughes, 2013; Neil Selwyn, 2021; Scherer et al., 2018). In China, TPACK framework has gained significant attention from researchers, and studies have been conducted to explore its applicability and effectiveness in the Chinese context (Hossain et al., 2021). This highlights the importance of understanding and promoting the use of technology in education in China, as well as the need for continued research on the role of TPACK in ICT integration in classroom teaching (Dong et al., 2015; Liu et al., 2014). This paper deals with the lack of TPACK among primary mathematics teachers in mainland China and their attitudes toward ICT integration in classroom teaching during the post-pandemic period. The paper aims to investigate the level of TPACK and attitudes toward ICT integration among mathematics teachers and identify any gender or teaching grade differences.

Research Background

In 2012, the Chinese government implemented the national education development of the 12th five-year plan (Ministry of Education of the People's Republic of China, 2012). The government expected that the intervention of the policy in the educational field could facilitate ICT integration in classroom teaching and teachers' ICT competencies (Zhang et al., 2018). Since the implementation of the policy, many researchers examined the factors impacting the effectiveness of ICT integration in classroom teaching. Mainly, the factors have been categorized into two aspects: internal factors (e.g., teachers' ICT competencies, teacher beliefs, attitude to ICT integration, and knowledge) and external factors (e.g., infrastructures, software, funding, and school management) (Zhang et al., 2018). From an external perspective, the Chinese government invested

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Contribution to the literature

- The study's findings and recommendations provide new insights into the challenges and opportunities of integrating digital technologies in mathematics teaching during the post-pandemic period.
- The study first combined TPACK instrument and ICT attitude instrument to measure primary mathematics TPACK and attitude toward ICT integration and underlines the significance of measuring teachers' attitudes towards ICT integration and how this can inform the design and implementation of effective TPACK development programs. This study provides a deeper understanding of TPACK of primary mathematics teachers in mainland China, and their attitudes towards ICT integration in the classroom, during the post-pandemic period.
- Also, this study can inform teacher education and policymakers to develop and implement more effective TPACK development programs tailored to primary mathematics teachers' specific needs.

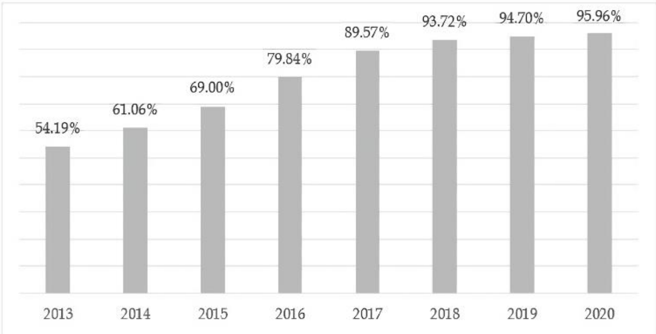

Figure 1. Proportion of primary schools that met standards for laboratory instruments in mathematics (Source: Author's own elaboration)

an amount of money on building ICT infrastructures and network since the beginning of the 21st century. An obvious example is that the proportion of primary schools that met the standards for laboratory instruments in mathematics surged from 54.19% to 95.96% (see **Figure 1**) from 2013 to 2020 in mainland China (Ministry of Education of the People's Republic of China, 2019). In other words, in 2020, most Chinese primary schools had sufficient resources (e.g., computers, experimental mathematics instruments, interactive whiteboard, and projectors) for mathematics classroom teaching.

While the Chinese government has made significant progress in improving the educational infrastructure and resources for ICT integration in classroom teaching, some researchers remain skeptical about the success of this integration. For instance, Chen et al. (2019) surveyed 3730 Chinese K12 teachers and pointed out that the government ignored the internal factors and had an insufficient evaluation on the whole process of educational reform. Additionally, Chen et al. (2019) asserted that ICT integration in classroom teaching was influenced by five main factors: application attitude, ICT-based teaching abilities, utilization frequency, application environment and degree of help. In contrast, Sang et al. (2011) debated that two significant factors came into play in the ICT integration: teachers' belief and attitudes toward computers in education. Indeed, these researchers have a resonance that the factors influencing ICT integration were complicated and interrelated instead of solving problems by merely improving infrastructures (Chen et al., 2019; Liu et al., 2014; Sang et al., 2011).

In recent years, some researchers advocated that mathematics teachers' TPACK played a crucial role in the transformation of traditional education and pointed out that the level of mathematics teachers' TPACK was positively linked to the effectiveness of ICT integration in classroom teaching (De Freitas & Spangenberg, 2019; Getenet et al., 2016; Liu et al., 2015). However, many primary mathematics teachers lacked TPACK in mainland China (Liu et al., 2015). It could be said that it is still challenging for primary mathematics teachers to integrate ICT into classroom teaching. Simultaneously, it also could be said that the goal of ICT integration is far from the Chinese government's anticipation. Previously, researchers have focused on the relationship between mathematics teachers' TPACK and ICT integration (Chai et al., 2011; Simsek & Sarsar, 2019). Differently, this study examines the relationship between mathematics teachers' TPACK and their attitudes towards ICT integration and the impact of large-scale online teaching on primary mathematics teachers' TPACK and attitudes towards ICT integration during the post-pandemic period in mainland China. Additionally, some studies have involved mathematics teachers' TPACK with different subjects' teachers (Chai et al., 2019; Schmidt et al., 2009). By contrast, this study explicitly targets primary mathematics teachers in mainland China who have experienced large-scale online teaching due to the COVID-19 pandemic. Importantly, this study is conducted in the post-pandemic period when schools have reopened after large-scale online teaching, which is a unique context that differs from previous studies (De Freitas & Spangenberg, 2019; Getenet et al., 2016; Liu et al., 2015).

In 2020, the outbreak of COVID-19 dramatically influenced the primary educational domain in mainland China. Large-scale online teaching has pushed teacher education to re-evaluate what key competencies the future mathematics teachers need to be equipped to effectively motivate millennium learners and adapt to the change of contemporary education (König et al., 2020). Currently, as schools reopen after the pandemic, it is important to understand the impact of large-scale online teaching on mathematics teachers' TPACK and attitudes towards ICT integration. Nevertheless, it is insufficient to teacher education concerning understanding the mathematics teachers' TPACK and their attitudes during the post-pandemic period. The unfamiliarity with mathematics teachers' TPACK and attitudes could negatively impact on the development of teacher education. Li (2012) contended that it is crucial to understand teachers' practical situation for teacher education, and the misjudgment of the teacher's actual situation will lead to the failure of teacher training. Moreover, research has shown that teachers' TPACK plays a critical role in successfully integrating ICT into teaching (Koh et al., 2010). However, more research needs to be conducted on mathematics teachers' TPACK and attitudes towards ICT integration in mainland China, especially during the post-pandemic period. Therefore, it is crucial to understand the impact of the pandemic on mathematics teachers' TPACK and attitudes towards ICT integration and to develop effective strategies to improve their skills in this area. The lack of mathematics teachers' TPACK and attitudes towards ICT integration has become a significant problem in contemporary education, especially in the post-pandemic period.

Therefore, this study aims to explore mathematics teachers' TPACK, their attitudes toward ICT integration, and their relationship after large-scale online teaching. The research questions formulated for this study will shed light on the perceptions of mathematics teachers in Chinese primary schools towards TPACK and ICT integration and how these relate to their demographic factors, such as gender, teaching experience, and teaching grade. By providing valuable insights for teacher education programs, policymakers, and school administrators, ultimately enhancing the quality of primary mathematics education in mainland China. Also, this study could contribute to the effective integration of ICT into mathematics teaching in the post-pandemic period and expand the existing literature on TPACK research in the context of primary mathematics education in mainland China. The following sections of this paper will provide an overview of the theoretical framework, research design and methodology, data analysis methods, results, and discussion, which collectively aim to answer the research questions and contribute to the existing literature on the impact of large-scale online teaching on primary mathematics teachers' TPACK and attitudes towards ICT integration in mainland China during the post-pandemic period.

Research Questions

1. What are the mathematics teachers' TPACK perceptions in a Chinese primary school?
2. What are the mathematics teachers' attitudes toward ICT integration in their classroom teaching after large-scale online teaching?
3. How might the mathematics teachers' demographic factors (genders, teaching experience, and teaching grade) relate to their knowledge domains of TPACK framework?
4. What are the relationships between the mathematics teachers' knowledge domains of TPACK framework and their attitudes toward ICT integration?

LITERATURE REVIEW

Theoretical Framework

TPACK, which built on the notion of pedagogical content knowledge (PCK) (Shulman, 1986) has been widely recognized as an essential competency to 21st century's teachers (Chai et al., 2019; Mishra & Koehler, 2006; Okumus et al., 2016). Moreover, as a fundamental theoretical framework, TPACK was introduced into many educational studies to comprehend pre-service and in-service teachers' knowledge required for ICT integration (Angeli et al., 2016; Chai et al., 2013). Many researchers believed that TPACK framework delineates what knowledge teachers have to be equipped to integrate ICT into classroom teaching effectively and how they could improve this knowledge (Schmidt et al., 2009; Stoilescu, 2015; Voogt et al., 2016). In the TPACK framework, three basic knowledge interact and form seven components of TPACK (**Figure 2**) (Mishra & Koehler, 2006). Koehler et al. (2013) defined the seven components, as follows:

1. **Technological knowledge (TK):** TK is the knowledge concerning a diversity of technologies, which contains traditional technologies (e.g., pen

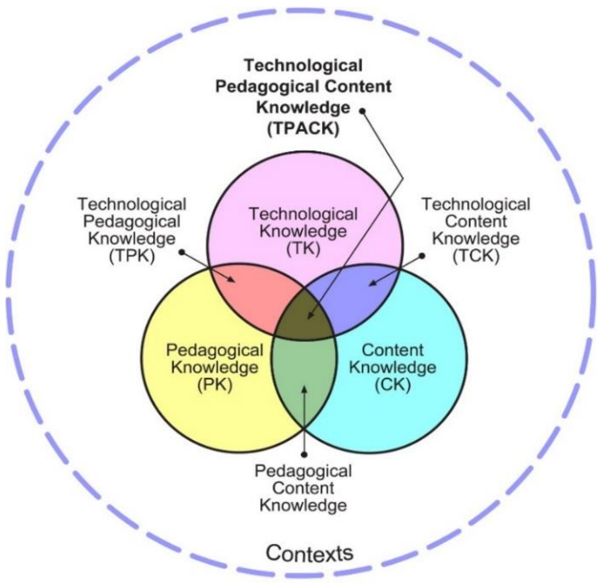

Figure 2. Components of TPACK framework (Mishra & Koehler, 2006) (http://tpack.org)

and paper) and digital technologies (e.g., interactive whiteboard, online teaching and learning platforms, applications).

2. **Content knowledge (CK):** CK refers to teachers' knowledge regarding the subject matter. It is teachers' knowledge concerning a specific subject matter to be taught or learned.
3. **Pedagogical knowledge (PK):** PK is defined as teachers' knowledge concerning teaching and learning methods. It includes knowledge in classroom management, student evaluation, student learning, and developing teaching plans.
4. **PCK:** PKC is similar to Shulman's (1986) definition that teachers' knowledge of pedagogy is the ability to teach unique content.
5. **Technological content knowledge (TCK):** TCK refers to comprehending the matter in which content and technology mutually impact and restrict. It suggests that teacher need to understand that they can utilize a specific technology to cope with subject-matter learning in their field.
6. **Technological pedagogical knowledge (TPK):** TPK is the knowledge that teachers can utilize different technologies to produce a positive impact on teaching and learning. This encompasses understanding the pedagogical restrictions and affordances of various technologies as they are associated with disciplinarily pedagogical designs.
7. **TPACK:** TPACK is the knowledge that teachers need to be equipped with to integrate technology into their teaching in a specific content domain. It is an understanding of interactions among three basic components: TK, CK, and PK.

TPACK framework has gained significant attention from researchers around the world for its potential to improve teaching and learning outcomes through effective integration of technology in education (Valtonen et al., 2017). Abbitt (2011) contended that the TPACK framework could make a difference in the pre-service teacher education (e.g., the utilization of the TPACK framework to assess and design pre-service teacher preparation programs). Moreover, the TPACK framework has also been introduced in different subject domains to understand teachers' abilities to integrate ICT. For example, in Australia, Prodromou (2015) investigated the relationship between mathematics teachers' TPACK and their ability for teaching statistics. Prodromou (2015) asserted that the development of mathematics teachers' TPACK was the antecedent of effectively applying mathematics teaching software to motivate students. In Australia, an increasing number of researchers believed that TPACK is the essential competence that mathematics teachers need to be equipped in the 21st century (Loong & Herbert, 2018; Prodromou, 2015).

In other countries, many researchers also believe that the TPACK framework plays an essential role in mathematics teacher education in the information age, such as in the USA (Smith et al., 2016) in South Africa (De Freitas & Spangenberg, 2019). It can be said that the practicability and significance of the TPACK framework have successfully attracted an increasing number of researchers' attention to investigate the profiles of pre-service and in-service teachers' TPACK. More importantly, as a contextualized synthesis of teacher knowledge, TPACK framework could be utilized to help teachers effectively integrate ICT in classroom teaching, thus better positively impact on student engagement and motivation to learn (Harris & Hofer, 2011; Mishra & Koehler, 2006; Okumus et al., 2016). Nevertheless, most studies were based on western countries' contexts, such as Turkey and the USA and rarely focused on the Chinese context (Scott, 2021).

TPACK in Mainland China

In mainland China, TPACK research mainly focused on the whole picture of teacher education instead of a specific subject domain such as mathematics teachers' TPACK. For example, Liu et al. (2015) investigated 2728 Chinese K12 in-service teachers' TPACK, which included primary and secondary all subjects' teachers. They found that these K12 in-service teachers' genders and ages were the significant elements, which could be utilized to predict teachers' TPACK (Liu et al., 2015). On the one hand, Chinese K12 male teachers had a strong sense in CK; nevertheless, female teachers had a strong sense in PCK. On the other hand, beginning teachers were perceived as more confident in TK than experienced teachers. Notably, the researchers indicated that the majority of K12 teachers lacked TPACK, and the lack of TPACK among the teachers prevented them from effectively integrating ICT in their classroom teaching (Liu et al., 2015). Furthermore, Wu et al. (2019) surveyed 2567 K12 teachers to explore the relationship between ICT integration and K12 schools' ICT supporting conditions in mainland China. The result revealed that rural schools and urban schools faced different dilemmas regarding the development of ICT integration. In rural areas, the schools faced both external barriers (e.g., insufficient infrastructure and inadequate funding) and internal barriers (e.g., the lack of TPACK among teachers) (Wu et al., 2019). By contrast, in the urban area, schools had ample resources (e.g., network and hardware). Nevertheless, urban teachers lacked technology-related abilities (e.g., TK, TPK, TCK, and TPACK) and attitude toward ICT integration, thus rarely utilizing these resources in their classroom teaching (Wu et al., 2019).

These studies focused on the overall evaluation of teachers' TPACK. There is insufficient empirical TPACK research linked to different disciplines and stages of compulsory education in mainland China (Zhang et al., 2018). While there have been some studies on the TPACK of K12 teachers in general, few have focused on TPACK of primary mathematics teachers specifically. Given the importance of TPACK in effective ICT integration and the increasing use of online teaching due to the COVID-19 pandemic, it is crucial to explore TPACK of primary mathematics teachers in China. Doing so can inform teacher education programs and provide insights into how to better support teachers in effectively integrating technology into their classroom teaching. Therefore, there is a pressing need for more empirical research on primary mathematics teachers' TPACK in mainland China.

Barriers of ICT Integration in Classroom Teaching

It is widely acknowledged that digital technologies play a significant role in improving students' learning outcomes in the current era (Alabdulaziz, 2021; Alneyadi et al., 2023). The factor influencing ICT integration in classroom teaching is crucial to educational informatization (Wu et al., 2019). However, since the beginning of the 21st century, ICT integration encountered various obstacles in many countries due to their different educational contexts (Noori, 2021). For instance, Lawrence and Tar (2018) pointed out that in some African countries such as Nigeria, there were seven factors, which prevented ICT adoption and integration in teaching: insufficient ICT knowledge, time limitation, unwillingness to change, the complexity of ICT integration, poor infrastructure, inadequate training, insufficient access and the lack of technical supports. In Afghanistan, no stable internet, lack of a stable power supply and lack of enough TK were the main problems in ICT integration in teaching and learning (Noori et al., 2022). In Australia, researchers believed that the primary barriers to the uptake of ICT and ICT utilization were problems with insufficient teacher confidence with ICT integration and fear of utilizing ICT (Skues & Cunningham, 2013). In the United Arab Emirates, Hamad et al. (2022) investigated the experiences of science teachers in integrating STEM approaches into their teaching and the challenges they face in doing so, such as documentation, curriculum content, and lack of supportive guidelines. They found that the biggest challenge for science teachers in integrating STEM approaches into their teaching is external challenges (e.g., the lack of supportive guidelines) (Hamad et al., 2022). Moreover, in mainland China, Zhang et al. (2018) claimed that the internal and external factors triggered the obstacles. The external factors encompassed insufficient funding for equipment, the weakness of school leadership, inadequate resources, and the lack of professional training (Bingimlas, 2009; Tay et al., 2014; Wu et al., 2019; Zhang et al., 2018). By contrast, internal factors were linked to teachers' beliefs, ability and attitude toward ICT integration (Blundell et al., 2020).

Although various barriers to ICT integration existed in different contexts, there was a similar phenomenon among them: many teachers lacked knowledge, attitudes, and skills to integrate ICT into their classroom teaching (Lawrence & Tar, 2018; Skues & Cunningham, 2013; Zhang et al., 2018). Therefore, it could be contended that in the information age, understanding teachers' capacity to integrate ICT and their attitudes toward ICT integration play a crucial role in the success of ICT integration in classroom teaching (Dong et al., 2015). To achieve the goal, many researchers believed that involvement of TPACK framework in teacher education is of importance because it could be used to explain ability that teachers need to be equipped for ICT integration in classroom teaching (Janssen & Lazonder, 2016; Stein et al., 2020). Simultaneously, they have faith that teachers' TPACK and their attitudes toward ICT integration also come into play in the transformation of traditional classroom teaching (Janssen & Lazonder, 2016; Kadioglu-Akbulut et al., 2023; Stein et al., 2020; Wang & Zhao, 2021). Accordingly, as an innovative and profound theoretical framework, TPACK is essential to development of contemporary education.

Teachers' Attitude Toward ICT Integration

As a crucial element of ICT integration in classroom teaching, teachers' attitudes toward ICT integration have been frequently discussed in many studies since the appearance of educational technology (Bindu, 2017; Gu et al., 2013; Scherer et al., 2018). Despite decades of discussion, the definition of teachers' attitudes toward ICT integration is of the inconclusiveness and inconsistency in the academic world. Some researchers associated teachers' attitudes with their behavior to account for the utilization of ICT, classroom activities and ICT-related material (Zhang et al., 2008). These researchers believed that teachers' attitudes toward ICT integration could be distinguished into two interaction aspects: object-oriented ICT attitudes and behavior-oriented ICT attitudes (Zhang et al., 2008). These researchers found that participants' attitudes toward digital technologies could be employed to predict the frequency of ICT utilization (Zhang et al., 2008). For instance, if teachers are interested in the interactive whiteboard, they will likely use it in their classroom teaching. By contrast, Scherer et al. (2015) hold different views and debated that the proper way to identify teachers' attitude toward ICT integration should be based on the functions of the technologies. They pointed out that teachers' attitudes toward ICT integration involved multidimensional factors including the usefulness of ICT for teaching and learning, the benefits of ICT usage for teaching performance, and students learning outcome (Scherer et al., 2015). In other words, Scherer et al. (2015) have faith that the attitudes toward ICT integration depend on what benefits technologies could be provided for teachers and students. It is apparent that these researchers defined teachers' attitudes toward ICT integration according to teachers' behavior and the function of digital technologies. However, these categories are difficult to explain teachers' attitudes toward ICT integration in classroom teaching accurately because of the insufficient consideration on classroom elements (e.g., classroom presentation, activities, teaching and learning resources preparation). By contrast, van Braak's (2001) category, attitudes toward computers in education, is more suitable for studies related to ICT integration in the classroom environment.

van Braak (2001) categorized teachers' attitudes into two aspects: attitudes toward computers in education scale and the general attitudes toward computers scale. He believed that teachers' attitude was an explanatory concept that could help comprehend the teachers' behavior toward computers (van Braak, 2001). van Braak et al. (2004) pointed out that on the one hand, teachers' general computer attitudes scale could be utilized to predict teachers' supportive computer use. For instance, teachers who liked work with computers were likely to prepare worksheets by computers (van Braak et al., 2004). On the other hand, the attitudes toward computers in education scale could be applied to predict class use of the computer (van Braak et al., 2004). An obvious example was that the teachers who believed that technology could make a difference in students' creativity were more willing to utilize computers for classroom teaching. It can be safely said that van Braak (2001) category crystallized the specific role of teachers' attitudes in ICT integration in classroom teaching. Last a decade, some researchers introduced the attitudes toward computers in education scale to measure and understand teachers' attitudes toward ICT integration in classroom teaching. In mainland China, Sang et al. (2011) examined 820 primary teachers' attitudes by utilizing van Braak's (2001) design. They argued that based on the Chinese context, teachers' attitudes toward ICT integration were influenced by three main factors: school-level factor (e.g., subject factor, infrastructures, school cultures, and leadership), social background factor (e.g., family background, economic status), and national level factor (e.g., the educational policy, curriculum reform) (Sang et al., 2011). It can be contended that this result highlighted the significance to take complex models into account to investigate teachers' attitudes toward ICT integration. Simultaneously, it underpinned the necessity to narrow down the research scope from the whole picture to specific discipline in different education levels, such as primary mathematics teachers. The study introduced van Braak (2001) attitudes toward computers in education scale to investigate primary mathematics teachers' attitudes toward ICT integration. The scale assesses several dimensions of attitudes towards technology, including perceived usefulness, perceived ease of use, anxiety, enjoyment, and risk-taking. Previous studies have used this scale to investigate teachers' attitudes towards technology integration in different contexts and subject domains (Ozdamli & Cavus, 2011). This scale can provide valuable insights into primary mathematics teachers' attitudes towards technology integration in China, and how these attitudes may have changed due to the COVID-19 pandemic.

METHOD

Research Design

Based on the deductive theory, researchers utilize previous theoretical ideas in a specific field to answer the research questions or deduce hypotheses (Bryman, 2016). This quantitative research project was designed as survey research with a deductive and positivist stance, and it employed a self-administered questionnaire (web-based and structured) to collect data. There were two practical reasons why the study chose the survey design and employed the web-based questionnaire. First, the research design considered two considerations: convenience and time limitation. The web-based survey solved these dilemmas (Dillman, 2014). Second, in the past, the questionnaire as an effective method has been widely utilized to examine pre-service and in-service teachers' TPACK and their attitudes in different contexts such as Australia (Petrea & Yehuda, 2019), South Africa (De Freitas & Spangenberg, 2019), China (Chai et al., 2013), Finland (Valtonen et al., 2017). These prior experiences were robust evidence to prove the reasonability of applying questionnaires to collect data. Hence, introducing the questionnaire was a feasible and reliable way to help the researcher effectively measure the teachers' TPACK and attitudes. Moreover, the researcher used a web-based application to design the questionnaires and generated QR code and link for participants to access the questionnaires. Then, the researcher used WeChat to deliver the web-based questionnaire because it was a convenient way for mathematics teachers to participate in the questionnaire. Studies have shown that it is crucial to provide participants with a convenient way to take part in the questionnaires because of its favorable influences on response rates (Bryman, 2016; Layder, 2013). Finally, the software package statistical package for the social sciences (SPSS, version 28) was employed for descriptive and inferential analysis.

Participants

As Cohen et al. (2018) mentioned, non-probability samples are convenient and less expensive for data collection. Therefore, during the post-pandemic period, the study applied the convenience sample strategy to recruit the participants from an urban primary school in Chongqing (southwest China).

In mainland China, pre-service teachers need up to at least four years of professional development to become in-service primary teachers (Li, 2012). During the four years, pre-service teachers are trained to be qualified teachers and obtain different primary teacher certifications, such as English and mathematics teacher certifications (Li, 2012). Thus, in most primary schools (typically in urban areas), different disciplines have different professional teachers (e.g., mathematics teachers, Chinese teachers, and English teachers). In this study, a convenience sample was used as it was a practical and cost-effective method of gathering data during the post-pandemic phase. Non-probability samples, such as convenience sampling, are frequently used in research because they are convenient and can give valid results under certain conditions, such as when the research is exploratory, or the sample is homogeneous and very large (Cohen et al., 2018; Etikan et al., 2016). In this case, the study focused only on in-service mathematics teachers in one primary school in Chongqing, China. The utilization of a convenience sample was determined to be a pragmatic and economical approach in contrast to a probability sample, which would have demanded a comprehensive exploration of potential participants across various primary schools and geographical locations (Etikan et al., 2016). However, it is essential to note that the generalizability of the findings may be limited due to the small sample size and non-random sampling method employed in this study. Therefore, caution should be exercised when extrapolating these results to other populations.

Data Collection

In this primary school, there were 34 in-service mathematics teachers, and all these teachers were invited to participate in the questionnaire voluntarily. Eventually, thirty-one valid questionnaires were collected, and three teachers rejected to participate in the study. It represents that the response rate was approximately 91.20%. The response rate of 91.20% indicates that a significant proportion (high level) of the population of in-service mathematics teachers in this primary school participated in the study (Cohen et al., 2018; Layder, 2013). Hence, it can be said that the 31 mathematics teachers could represent the population of mathematics teachers in this primary school. However, it is important to note that the population of 34 in-service mathematics teachers is not representative of the whole population of interest in mainland China. Consequently, the outcomes of this study may possess restricted generalizability in more extensive settings, thereby necessitating caution when applying them to other contexts.

Additionally, the samples covered all grades (from grade one to grade six) in this primary school. In questionnaire design research, two primary elements need to be considered when doing data collection: the data collection tools and the questionnaire delivery way (Cohen et al., 2018; Punch & Oancea, 2014). To deal with the two primary issues, the researcher used Wenjuanxing (WJX) and WeChat to collect data. WJX is a SurveyMonkey-like online platform in mainland China. Hence, the researcher applied WJX to design the web-based questionnaires and generated the QR code and link for participants to access the questionnaires. WeChat is a WhatsApp-like social media, and in this primary school, teachers communicate and collaborate with colleagues in everyday work via WeChat. Hence, WeChat was a convenient way for mathematics teachers to participate in the questionnaire. The questionnaires were distributed via WeChat, and this strategy contributed to the high response rate.

The Instrument

Reliability and validity

The study introduced the questionnaires designed by Schmidt et al. (2009) and van Braak (2001) to gauge the mathematics teachers' TPACK and attitudes toward ICT integration in classroom teaching. There were three parts to the questionnaires. In the first part, the questionnaire collected the mathematics teachers' demographic information, including three items (gender, years of teaching experience, and teaching grade). The second part measured mathematics teachers' TPACK (Schmidt et al., 2009). There were 37 items in this part, categorised into seven dimensions: seven TK items, three CK items, seven PK items, four PCK items, four TCK items, five TPK items, and seven TPACK items. Moreover, the participants completed the 37 questions via the five-point Likert scale (strongly disagree, disagree, neither agree nor disagree, agree, and strongly agree). In the third part, attitudes toward computers in education scale (van Braak, 2001) was introduced to examine mathematics teachers' attitudes. There were 12 items in this part, designed based on the five-point Likert scale.

The instrument's validity and reliability play a significant role in research (Bryman, 2016; Cohen et al., 2018). In this research project, the validity and reliability of the questionnaires were identified. The questionnaire (Schmidt et al., 2009; van Braak, 2001) was based on piloting questionnaires, which help to identify and eliminate confusing or unreliable questions, prevent irrelevant questions, and ensure a clear structure (Gray, 2018). In addition, the questionnaire was based on Cronbach's alpha reliability analysis and factor analysis. In TPACK part, the internal consistency of the seven dimensions was as the following: TK (0.82), CK (0.85), PK (0.84), PCK (0.85), TCK (0.80), TPK (0.86), and TPACK (0.92) (Schmidt et al., 2009). Also, the questionnaire (Schmidt et al., 2009) was introduced and validated via confirmatory factor analysis (CFA) in different contexts, such as Turkey (χ^2/df=2.21, RMSEA=.05, SRMR=.08) (Cetin & Erdogan, 2018), Finland (χ^2=863.2, p<.01, CFI=.98, RMSEA=.063) (Valtonen et al., 2017), and Singapore (χ^2=1079.55, χ^2/df=2.60, p<.001, TLI=.945, CFI=.951, SRMR=.045) (Chai et al., 2011). Hence, it can be said that the scale's validity has been tested and validated in various contexts. Moreover, the ICT attitude part had high alpha reliability of 0.89 (van Braak, 2001). It is worth noting that the questionnaires used in this research project have been widely used in various studies in different countries, including China (Liu et al., 2015), indicating their robust reliability and validity.

Piloting

The questionnaires (Schmidt et al., 2009; van Braak, 2001) were used based on the Chinese context. Hence, several examples were used after some items to help participants accurately understand the meaning of the questions. For example, the original item from Schmidt et al. (2009) is "I know how to solve my own technical problems". The author added the examples in this item as the following: I know how to solve my own technical problems (e.g., teaching software cannot be used normally, PPT needs to insert video animation and so on). Moreover, although the instrument was adopted from previous valid and reliable questionnaires, its reliability and validity still need to be verified because of the translation of the questionnaires from English to Chinese. On the one hand, a professional translation panel was established. A Chinese teacher (in China) and my colleague (in Australia) were invited to collaborate via Zoom to translate the questionnaires accurately and authentically. Three of us have same mother language (mandarin) and second language (English). On the other hand, for testing the reliability of questionnaires (Chinese version), The researcher invited 30 mathematics teachers in another primary school to do the piloting test. CFA cannot be used to test the validity of the scale due to the limited samples (Byrne, 2016). The internal consistency (Cronbach's alpha reliability analysis) was performed in **Table 1**. It is evident that according to Cohen et al. (2018) alpha coefficient guideline, the internal consistency in the majority of subscales was reliable. Therefore, it could be concluded that the questionnaire (Chinese version) was of reliability and validity in this study (**Appendix A**).

Table 1. Cronbach's alpha analysis for reliability

Research variables	Cronbach's alpha	Numbers of items
TK	.793	7
CK	.723	3
PK	.705	7
PCK	.738	4
TCK	.743	4
TPK	.734	5
TPACK	.860	7
Attitudes to ICT	.813	12

Data Analysis

In the TPACK data analysis part, the researcher employed descriptive analysis methods to analyze the variables of TPACK to answer research question one. Therefore, the means (M) and standard deviations (SD) of seven TPACK framework elements were calculated, evaluated, and compared with previous studies' findings. Second, to answer research question two, the study analyzed the means, standard deviation, median, and mode of the variables of teachers' attitude scale to articulate mathematics teachers' current attitudes toward ICT integration. Subsequently, the study introduced inferential analysis to answer research questions three and four. The independent sample T-test (de Winter, 2013) and Mann-Whitney U test (Ruxton, 2006) were applied to gauge the influences of gender differences on the mathematics teachers' TPACK. Also, the researcher utilized descriptive analysis methods to measure the seven elements of TPACK framework according to the mathematics teachers' teaching experience in years. This analysis helped the study understand the mathematics teachers' TPACK according to their various teaching experiences. Additionally, this analysis was the antecedent of further evaluation (independent sample T-test and Mann-Whitney U test) to reveal the relationship between teachers' teaching experience and TPACK. In addition, independent sample t-test and Mann-Whitney U test were employed to analyze grade differences' influences on the mathematics teachers' TPACK (Cohen et al., 2018). Finally, the study used Spearman's rank correlation analysis to reveal the relationship between the mathematics teachers' knowledge domains of TPACK framework and their attitudes toward ICT integration.

RESULTS

The results were delineated according to the four main research questions in the same order. The grades, teaching experience, and genders of the mathematics teachers were demonstrated in **Table 2**, providing a summary of the characteristics of the study participants.

What are the Mathematics Teachers' TPACK Perceptions in a Chinese Primary School?

Table 3 illustrates that scores of seven TPACK dimensions are relatively high, and they are all above the mid-point three. Moreover, the mathematics teachers were strongly confident of their PCK (M=4.02, SD=.36) and PK (M=4.00, SD=.38). On the contrary, they rated themselves as comparatively unconfident in TK (M=3.53, SD=.63) and TPACK (M=3.58, SD=.58). Remarkably, the mathematics teachers perceived that they were the weakest in TCK (M=3.40, SD=.60). It is

Table 2. Demographic information

Variable	Frequency	Valid percentage
Grade		
1-3	19	61.3
4-6	12	38.7
Total	31	100.0
Teaching experience		
0-5 years	8	25.8
6-10 years	5	16.1
11-15 years	6	19.4
16+ years	12	38.7
Total	31	100.0
Gender		
Male	7	22.6
Female	24	77.4
Total	31	100.0

Table 3. Mathematics teachers' TPACK statistics

Types	Numbers (n)	Items	M	SD
TK	31	4-10	3.53	.63
CK	31	11-13	3.91	.49
PK	31	14-20	4.00	.38
PCK	31	21-24	4.02	.36
TCK	31	25-28	3.40	.60
TPK	31	29-33	3.81	.50
TPACK	31	35-40	3.58	.58

evident that the mean scores of the non-technology-related dimensions (CK, PK, and PCK) are greater than the mean scores of the technology-related dimensions (TK, TCK, TPK, and TPACK). Therefore, the data suggest that TPACK training needs to pay more attention to mathematics teachers' technology-related abilities.

What are the Mathematics Teachers' Attitudes Toward ICT Integration in Their Classroom Teaching After Large-Scale Online Teaching?

Table 4 demonstrates the attitudes information collected from the mathematics teachers. According to Table 4, except the item50 (M=3.97, SD=.84) and the lowest mean score of item52 (M=3.35, SD=1.02), the mean scores of other ten items (83.30% of total) in this scale are all greater than four (agree), particularly the highest score of item49 (M=4.35, SD=.49).

Meanwhile, Table 4 shows that the mean score of all items (M=4.09, SD=.46) is slightly over four (agree). Furthermore, 11 of 12 items (91.70% of total) are four (agree) in the median, and only item52 is three (neither agree nor disagree). Although the mode of item52 is three (neither agree nor disagree), the mode from item41 to item50 (83.30% of total) is four (agree), especially the mode of item51 is five (strongly agree). Accordingly, it is apparent that during the post-pandemic period, the mathematics teachers had a high positive perception of ICT integration in their classroom teaching.

Table 4. Mathematics teachers' attitudes toward ICT integration description

Items	n	Mean	Median	Mode	SD
41	31	4.00	4	4	1.03
42	31	4.19	4	4	.48
43	31	4.06	4	4	.57
44	31	4.19	4	4	.54
45	31	4.32	4	4	.60
46	31	4.00	4	4	.78
47	31	4.19	4	4	.70
48	31	4.16	4	4	.78
49	31	4.35	4	4	.49
50	31	3.97	4	4	.84
51	31	4.32	4	5	.70
52	31	3.35	3	3	1.02
Mean score of items		4.09	4.17	4.17[a]	.46

Note. [a]Multiple modes exist & the smallest value is shown

How Might the Mathematics Teachers' Demographic Factors (Genders, Teaching Experience, and Teaching Grade) Relate to Their Knowledge Domains of TPACK Framework?

Table 5 and Table 6 delineate the relationship between mathematics teachers' gender and TPACK. Table 6 shows that there is a statistically significant difference in TK (p=.007) between female (n=24) and male (n=7) teachers, which means the null hypothesis should be rejected. Nevertheless, according to Fritz et al. (2012), the effect size (ES) is small (ES=.49). Moreover, there is no significant difference between female and male teachers for the other six knowledge domains of the TPACK framework: CK, PK, PCK, TCK, TPK, and TPACK (p>.05 for all), which means the null hypothesis should be accepted. ES for these variables are relatively small, ranging from .19 to .72. According to Cohen's d (Cohen et al., 2018), ESs in Table 5 can be considered small. This indicates that although there may be slight differences between male and female teachers regarding their CK, PK, PCK, TCK, TPK, and TPACK scores, these differences are not large enough to be statistically significant. The result suggests that gender difference may not be an essential factor influencing mathematics teachers' TPACK. Therefore, teachers' gender may not be an important factor in developing TPACK training programs for mathematics teachers.

Furthermore, Table 7 demonstrates that the teachers (N=8) who have zero-five years of teaching experience, rated themselves less than other mathematics teachers in PK (M=3.77, SD=.30) and PCK (M=3.78, SD=.21). Also, the teachers (n=5) who have six-10 years of teaching experience were most confident in TK (M=3.86, SD=.29), TCK (M=3.85, SD=.22), and TPK (M=4.04, SD=.46) despite gaining the lowest scores in CK (M=3.53, SD=.56) and TPACK (M=3.26, SD=.62). On the contrary, the teachers (n=6) who has 11-15 years of teaching experience, expressed the most unconfident in TCK (M=3.13, SD=.44) and TPK (M=3.70, SD=.39).

Table 5. Independent samples t-tests result concerning gender difference

	Gender	Descriptive information			Levene's test		t-test for equality of means			
		Number	Mean	SD	F	Sig.	t	df	Sig. (2-tailed)	ES
PK	Male	7	4.06	.28	.60	.44	.44	29	.66	.19
	Female	24	3.99	.41						
PCK	Male	7	4.18	.24	2.63	.12	1.38	29	.18	.59
	Female	24	3.97	.38						
TCK	Male	7	3.64	.50	1.29	.27	1.20	29	.24	.52
	Female	24	3.33	.62						
TPK	Male	7	4.09	.34	1.52	.23	1.68	29	.10	.72
	Female	24	3.73	.52						
TPACK	Male	7	3.84	.53	.01	.94	1.37	29	.18	.59
	Female	24	3.50	.59						
Attitudes toward ICT	Male	7	4.19	.41	.10	.75	.63	29	.54	.27
	Female	24	4.06	.48						

Note. ES: Effect size

Table 6. Non-parametric tests 2 independent samples tests result concerning gender difference

	Gender	n	Mean rank	Sum of ranks	Mann-Whitney U	Wilcoxon W	Z	A. sig. (2-tailed)	ES: $r^2 = (\frac{z}{\sqrt{n}})^2$
TK	Male	7	24.14	169	27	327	-2.709	.007	.49
	Female	24	13.63	327					
CK	Male	7	14.21	99.5	71.5	99.5	- .61	.542	.11
	Female	24	16.52	396.5					

Note. A: Asymptotic

Table 7. Teaching experience in years & TPACK descriptive statistics

Teaching	TK		CK		PK		PCK		TCK		TPK		TPACK	
experience in years	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
0-5 years (n=8)	3.46	.48	3.83	.44	3.77	.30	3.78	.21	3.63	.53	3.85	.42	3.70	.34
6-10 years (n=5)	3.86	.29	3.53	.56	3.83	.26	3.90	.42	3.85	.22	4.04	.46	3.26	.62
11-15 years (n=6)	3.76	.42	3.94	.44	4.17	.23	4.29	.10	3.13	.44	3.70	.39	3.81	.45
15+ years (n=12)	3.33	.85	4.11	.48	4.15	.44	4.08	.40	3.21	.71	3.75	.63	3.51	.73

However, these teachers obtained the highest scores in PK (M=4.17, SD=.23), PCK (M=4.29, SD=.10), and TPACK (M=3.81, SD=.45). Finally, the teachers (n=12) who have more than 15 years of teaching experience, were most confident in CK (M=4.11, SD=.48); however, they gained the lowest score in TK (M=3.33, SD=.85). The data uncovered that teacher with different teaching experience had various strengths and weaknesses in the seven elements of TPACK framework. There is, therefore, a clear need to further examine the relationship between mathematics teachers' teaching experience and TPACK.

Table 8 and **Table 9** shed light on the relationship between teachers' teaching experience and their TPACK. First, the data reveals that with a large ES, there is a significant difference in CK (p=.047, ES=-1.15) between teachers who have six-10 years of teaching experience and teachers who have more than 15 years of teaching experience.

Moreover, **Table 7** illustrates that the mathematics teachers who have 11-15 years of teaching experience rated themselves as more competent in PK and PCK than the teachers who have zero-five years of teaching experience. Importantly, further analysis has shown that a statistically significant difference also can be found between the two groups of teachers in PK (p<.05, ES=-1.45) and PCK (p<.01, ES=.86).

Further, the mathematics teachers who have six-10 years of teaching experience were significantly different from the teachers who have 11-15 years of teaching experience in TCK with a medium ES (p=.011, ES=.77). It is evident that teaching experience plays an essential role in predicting mathematics teachers' TPACK. Therefore, it can be safely said that mathematics teacher education should take teachers' teaching experience into account when designing TPACK professional development programs.

Finally, **Table 8** and **Table 9** also reveal the relationship between lower-grade mathematics teachers (grade 1-3, n=19) and higher-grade mathematics teachers (grade 4-6, n=12) for the seven elements of TPACK framework. Interestingly, there is no statistically significant difference between the two groups of teachers in all elements of the TPACK framework (p>.05 for all) except PCK (p=.024). However, ES of PCK (ES=.41) is small. Thus, like gender difference, the authors believes that grade difference probably is not an essential factor in TPACK teacher training.

Table 8. Independent samples t-tests result concerning teaching experience in years & grade level

	Teaching experience in years	Descriptive information			Levene's test		t-test for equality of means			
		n	Mean	SD	F	Sig.	t	df	Sig. (2-tailed)	ES
TK	6-10 years	5	3.86	.29	2.767	.117	1.326	15	.205	.71
	15+ years	12	3.33	.85						
CK	6-10 years	5	3.53	.56	.139	.714	-2.167	15	.047*	-1.15
	15+ years	12	4.11	.48						
PK	0-5 years	8	3.77	.30	.837	.378	-2.678	12	.020*	-1.45
	11-15 years	6	4.17	.23						
TPACK	6-10 years	5	3.26	.62	.739	.412	-1.719	9	.120	-1.04
	11-15 years	6	3.81	.45						
	Grade level									
CK	Grade 1-3	19	3.84	.48	.016	.900	-1.02	29	.316	-.38
	Grade 4-6	12	4.03	.52						
PK	Grade 1-3	19	3.93	.37	.098	.756	-1.348	29	.188	-.50
	Grade 4-6	12	4.12	.38						
TCK	Grade 1-3	19	3.37	.65	1.464	.236	-.398	29	.694	-.15
	Grade 4-6	12	3.46	.54						
TPACK	Grade 1-3	19	3.56	.49	3.276	.081	-.232	29	.818	-.09
	Grade 4-6	12	3.61	.72						

Note. **p<.01 (2-tailed) & *p<.05 (2-tailed)

Table 9. Non-parametric tests 2 independent samples tests result concerning teaching experience in years & grade level

	Teaching in years	n	MR	SR	Mann-Whitney U	Wilcoxon W	Z	A. sig. (2-tailed)	ES: $r^2 = (\frac{z}{\sqrt{n}})^2$
PCK	0-5 years	8	4.5	36	<.001	36	-3.202	.001	.86
	11-15 years	6	11.5	69					
TCK	6-10 years	5	8.7	43.5	1.5	22.5	-2.547	.011	.77
	11-15 years	6	3.75	22.5					
TPK	6-10 years	5	7.5	37.5	7.5	28.5	-1.392	.164	.42
	11-15 years	6	4.75	28.5					
	Grade level								
TK	Grade 1-3	19	14.87	282.5	92.5	282.5	-.877	.380	.16
	Grade 4-6	12	17.79	213.5					
PCK	Grade 1-3	19	13.16	250	60	250	-2.257	.024	.41
	Grade 4-6	12	20.5	246					
TPK	Grade 1-3	19	15.95	303	113	303	-.041	.967	.01
	Grade 4-6	12	16.08	193					

Note. MR: Mean rank; SR: Sum of ranks; & A: Asymptotic

What are the Relationships Between the Mathematics Teachers' Knowledge Domains of TPACK Framework and Their Attitudes Toward ICT Integration?

Table 10 indicates a moderately significant relationship between the mathematics teachers' attitudes toward ICT integration and their TPACK domain knowledge (r=.448, p=.011). However, the mathematics teachers' attitudes insignificantly related to the other six elements of TPACK framework: TP, CK, PK, PCK, TCK, and TPK (p>.05 for all).

This finding is robust evidence to prove that some non-TPACK factors probably influenced mathematics teachers' attitudes toward ICT integration. Although limited relationship could be found between teachers' attitudes and their TPACK in this study, the result revealed some positive relationship among the seven elements of TPACK framework.

Table 9 has shown that there is a moderately positive significant relationship between TK and TPACK (r=.509, p=.003) as well as PK and TPACK (r=.460, p=.009). Remarkably, TPACK has the highest positively significant relationship with TPK (r=.643, p<.001). Furthermore, there are several other moderately positive significant relationships can be found: TPK and TK (r=.555, p=.001), TPK and TCK (r=.452, p=.011), TCK and TK (r=.439, p=.013), PCK and PK (r=.489, p=.005), and PK and CK (r=.398, p=.027). These complicated relationships between different elements reveal crucial information that the seven elements of TPACK framework are likely to be reciprocal and synergistic. There is, therefore, a clear need that TPACK training should take all seven elements of TPACK framework into account, and TPACK training should be differentiated according to mathematics teachers' practical situations.

Table 10. TPACK & attitudes toward ICT integration Spearman's correlation results

		TK	CK	PK	PCK	TCK	TPK	TPACK
TK	Correlation coefficient	1						
	Sig. (2-tailed)							
CK	Correlation coefficient	-.123	1					
	Sig. (2-tailed)	.511						
PK	Correlation coefficient	.125	.398*	1				
	Sig. (2-tailed)	.503	.027					
PCK	Correlation coefficient	.192	.321	.489**	1			
	Sig. (2-tailed)	.301	.078	.005				
TCK	Correlation coefficient	.439*	-.174	.104	.042	1		
	Sig. (2-tailed)	.013	.35	.579	.823			
TPK	Correlation coefficient	.555**	-.08	.316	.048	.452*	1	
	Sig. (2-tailed)	.001	.67	.083	.796	.011		
TPACK	Correlation coefficient	.509**	.126	.460**	.216	.204	.643**	1
	Sig. (2-tailed)	.003	.5	.009	.243	.27	< .001	
Attitudes toward ICT integration	Correlation coefficient	.255	.046	.254	-.199	.032	.289	.448*
	Sig. (2-tailed)	.167	.804	.168	.283	.865	.115	.011

Note: *Correlation is significant at .05 level (2-tailed) & **Correlation is significant at .01 level (2-tailed)

DISCUSSION

Weakness of Current Primary Mathematics Teachers

Table 3 revealed the profiles of the mathematics teachers' TPACK in the primary school, and it also uncovered the relationship between these teachers' technology-related factors (TK, TPK, TCK, and TPACK) and non-technology-related factors (PK, CK, and PCK). In this primary school, the mathematics teachers tended to perceive themselves as having sufficient confidence in PCK, PK, and CK. In other words, the mathematics teachers believed they had enough mathematics knowledge and knowledge regarding teaching and learning methods (e.g., classroom management, student evaluation, student learning, and developing teaching plans). Moreover, they also rated themselves in strong confidence to effectively utilize pedagogy to deliver mathematics curriculum. This finding echoed previous studies concerning in-service teachers' TPACK (Koh et al., 2014; Liu et al., 2015). However, in this study, the mathematics teachers' TPK was slightly lower than PCK, PK, and CK, which is different from Liu et al. (2015). They claimed that Chinese in-service K12 teachers perceived that they were insufficient in TPK (Liu et al., 2015).

Nevertheless, in this study, many mathematics teachers (87.10% of the total) claimed that they were willing to use digital technologies to improve their classroom teaching quality. Even 74.20% of mathematics teachers responded that they could choose a diversity of technologies to enhance their teaching approaches. Thus, to some extent, the result indicates that after large-scale online teaching, mathematics teachers expressed relatively confident in teaching with digital technologies (e.g., utilizing DingTalk to manage the classroom, applying Seewo interactive whiteboard to teach, using mathematical software to assist classroom teaching).

In summary, the result uncovered that during the post pandemic period, the mathematics teachers lacked confidence in technology-related knowledge: TK, TCK, and TPACK. However, they were relatively confident in utilizing digital technologies to improve their teaching methods. Interestingly, there was a phenomenon in this primary school that the mean scores of all technology-related factors (TK, TPK, TCK, and TPACK) were dramatically less than the non-technology-related factors (PK, CK, and PCK). The phenomenon could also be found in previous studies (De Freitas & Spangenberg, 2019; Liu et al., 2015). With a similar view to Dong et al. (2015) and Wu et al. (2019), the author believes that insufficient technology-related knowledge could hinder ICT integration in their classroom teaching and lead to teacher professional development failure in the digital era. Therefore, it could be argued that mathematics teacher training should pay more attention to the development of the four knowledge domains (TK, TPK, TCK, and TPACK) and systematically design TPACK professional development projects according to the practical training needs of primary mathematics teachers.

An Urgent Need in Mathematics Teacher Education During the Post-Pandemic Period

In this research project, the instrument from van Braak (2001) was introduced to gauge the mathematics teachers' attitudes toward ICT integration in their classroom teaching. According to **Table 4**, the mean score of items is significantly high, and it is dramatically greater than the mean score conducted in the previous study with the same scale in mainland China (Sang et al., 2010). Additionally, 11 items' (91.7%) median is four (agree), and ten items' (83.3%) mode is four (agree). Notably, all mathematics teachers believed that digital technologies' involvement could help students better understand geometric concepts (item49), and further analysis has shown that there is a statistically positive relationship between this item and teachers' mean scores of items (r=.547, p=.001). Accordingly, the author believes that there is a clear need to explore relationship between teachers' attitudes toward digital technologies and geometry teaching in the future. Eventually, the analysis of three dimensions (mean, median and mode) statistically proved that during the post pandemic, most of the mathematics teachers in this primary school are willing to change their teaching approaches and adopt new technologies in their classrooms.

Furthermore, this result also emphasized the significance of teachers' attitudes in ICT integration in classroom teaching. Previous studies underlined that favorable attitudes toward ICT integration in teaching could positively impact the willingness to adopt change and the frequency of ICT utilization in the classroom (Sang et al., 2011; van Braak et al., 2004). In this study, the finding echoed this concept. Although many mathematics teachers lacked the technology-related ability (e.g., TK, TPK, TCK, and TPACK), they still expressed their willingness to apply digital technologies in their classroom teaching during the post-pandemic period. Therefore, with similar perspectives of previous studies, the author advocates that teachers' attitudes toward ICT integration need to be evaluated before implementing ICT integration projects (Baturay et al., 2017; Bindu, 2017). It can be safely said that there is an urgent need to measure mathematics teachers' attitudes toward ICT integration during the post-pandemic period before implementing TPACK development programs because it helps to understand how willing and ready mathematics teachers are to incorporate digital technologies in their teaching practices. This information is crucial for the successful implementation of TPACK development programs, as teachers with positive attitudes toward ICT integration are more likely to engage in professional development activities and adopt new teaching practices involving technology (Chai et al., 2010; Voogt et al., 2013). On the other hand, teachers with negative attitudes may resist the implementation of ICT integration programs and may require additional support and training to overcome their barriers to technology adoption (Angeli & Valanides, 2009; Ertmer & Ottenbreit-Leftwich, 2010). Therefore, measuring teachers' attitudes toward ICT integration can help to inform the design and implementation of effective TPACK development programs that address the specific needs of mathematics teachers during the post-pandemic period.

Needs to Design Differentiated Training for Primary Mathematics Teachers

The novel and important finding of the current study revealed the relationship between the mathematics teachers' TPACK and their three demographic factors: gender, teaching experience and teaching grade.

Gender

Previous studies found that there was a statistically significant difference between male and female teachers in teachers' CK, PCK (Liu et al., 2015), TK, TCK (Baturay et al., 2017; Koh et al., 2014), and TPACK (Koh et al., 2014). For example, Baturay et al. (2017) found that male teachers perceived that computers were more proper to themselves and more capable of technology-related tasks than female teachers. By contrast, Liu et al. (2015) pointed out that many Chinese K12 in-service female teachers believed that they were more capable than male teachers in using a diversity of teaching methods to deliver learning content (PCK). When the study narrowed the sample from all subjects' teachers to primary mathematics teachers, the result is different from some previous studies. In this study, male teachers and female teachers have different advantages and disadvantages in the seven components of TPACK framework. Male mathematics teachers were confident in solving technical problems and utilizing a diversity of digital technologies. Female mathematics teachers believed that they were more capable of mathematics CK. However, there is no significant difference in CK, PK, PCK, TCK, TPK, and TPACK. Although significant gender difference exists in the mathematics teachers' TK, ES=.49 is small. Thus, it can be said that gender difference has a limited influence on the mathematics teachers' TPACK. This result is consistent with the previous finding conducted by Chai et al. (2019). Therefore, it could be argued that gender difference is not an essential consideration in the mathematics teachers' TPACK development program.

Teaching experience

Based on the teaching experience classification in years (see **Table 7**), the young mathematics teachers (zero-five years) perceived that they lacked knowledge in classroom management, student evaluation and teaching strategies. On the contrary, the experienced mathematics teachers (11-15 years and 15+ years) believed that they could utilize a diversity of teaching approaches to engage and motivate students, yet unconfident in applying digital technologies such as interactive whiteboard and mathematics software. This finding echoed the previous studies that senior teachers were confident in CK and PCK; however, they were unwilling to use digital technology in their classroom teaching (Koh et al., 2014; Liu et al., 2015). More importantly, according to **Table 8** and **Table 9**, the author found that teaching experience could be employed to predict mathematics teachers' TPACK because, among the four groups, their relationships existed a statistically significant difference in CK (ES=-1.15), PK (ES=-1.45), PCK (ES=.86), and TCK (ES= .77). It can be said that the result manifests the importance of teaching experience factor in developing TPACK training programs for mathematics teachers.

Therefore, mathematics teachers' teaching experience should be considered as an essential element in mathematics teachers' TPACK professional development. This underscores the importance of designing TPACK training programs that consider the different needs of teachers at different stages of their careers (Ertmer et al., 2012).

Teaching grade

Previous studies lacked evidence to explain the influence of the teaching grade to teachers' TPACK. Koh et al. (2014) suggested that it is necessary to examine the relationship between teaching grade and teachers' TPACK for effectively designing teacher TPACK development programs. For filling the research gap, this study preliminarily investigated teaching grade influence on mathematics teachers' TPACK. The mathematics teachers were divided into two groups: teachers (n=19) from grade one to grade three, teachers (n=12) from grade four to grade six. The result suggests that except PCK (p=.024, ES=.41), there is no statistically significant difference in the other six knowledge domains between the two groups of teachers. It is apparent that teaching grade is hard to be utilized to predict mathematics teachers' TPACK. Therefore, it could be contended that teaching grade classification (grade 1-3 and grade 4-6) is not an essential factor that should be considered in designing the TPACK development programs. It is worth, however, to noting that this study has a small sample size, and it may also be worthwhile to conduct further research with larger sample sizes and more diverse populations to better understand the relationship between teaching grade and TPACK.

Enlightenment of the High-Level Positive Correlation Relationship

According to **Table 10**, the data suggests that in the TPACK framework, the seven elements have multiple sets of positive correlations with each other. However, the mathematics teachers' attitude toward ICT integration is only positively related to TPACK knowledge domain. The result uncovers that the seven components of TPACK are not mutually exclusive; instead, each of the seven components impacts others. For instance, if the mathematics teachers lacked TK, it could negatively influence their TCK, TPK, and TPACK. This result is consistent with the previous studies (Angeli & Valanides, 2009; De Freitas & Spangenberg, 2019; Sang et al., 2010). Moreover, the positive relationship between these elements implies that mathematics teachers' TPACK need to be reviewed as an integrative perspective instead of the independent element (Angeli et al., 2016). Although the mathematics teachers' attitudes toward ICT integration positively correlate with their TPACK knowledge domain, the correlation coefficient is small (Spearman's correlation coefficient=.448). In other words, during the post-pandemic period, some mathematics teachers with insufficient technology-related knowledge also had positive attitudes toward utilizing digital technologies (e.g., Seewo interactive whiteboard, DingTalk and mathematics teaching software) in their classroom teaching. However, there is insufficient evidence to explain what reasons led to the positive relationship between mathematics teachers' TPACK and their attitudes towards ICT integration in classroom teaching and why the correlation coefficient is low. This hints that other factors probably influenced mathematics teachers' attitudes toward ICT integration. For instance, their attitudes might be influenced by the traditional culture, teaching environment (Sang et al., 2011), and the online teaching experience during the pandemic (Bryson & Andres, 2020). Therefore, while the positive relationship between mathematics teachers' TPACK and their attitudes towards ICT integration is noteworthy, it is essential to recognize that other factors could be at play (Tondeur et al., 2017). Further investigation is needed to fully understand this relationship.

CONCLUSIONS

Based on TPACK framework, this study focused on Chinese primary mathematic teachers' TPACK and examined their attitudes toward ICT integration. The result provides teacher education with current information concerning primary mathematics teachers' TPACK and their attitudes during the post-pandemic period. The results can also benefit mathematics teacher education and help mathematics teachers better integrate ICT into their classroom teaching. In addition, this study expands TPACK research boundary because it brought Chinese primary mathematics teachers into TPACK research field.

This study explored mathematics teachers' TPACK and their attitudes, and the conclusion could be linked to three aspects. First, in this Chinese primary school, the mathematics teachers believed they lacked technology-related knowledge and were confident in non-technology-related ability. Therefore, TPACK professional training should focus on improving mathematics teachers' TK, TPK, TCK, and TPACK. Second, during the post-pandemic period, most of the mathematics teachers in this primary school expressed positive attitudes to applying various digital technologies (e.g., Seewo interactive whiteboard and DingTalk) in their classroom teaching. Third, concerning mathematics teachers' demographic factors (gender, teaching experience, and grade), teaching experience is a crucial factor, which needs to be considered in their TPACK development. On the one hand, young teachers were confident in using digital technologies yet felt insufficient in non-technology-related knowledge (CK, PK, and PCK).

On the other hand, experienced mathematics teachers believed they lacked technology-related knowledge to effectively integrate ICT into their classroom teaching. Furthermore, correlation analysis (see **Table 10**) shows that the seven components of TPACK framework were reciprocal and synergistic. Therefore, it could be argued that before implementing any TPACK development program, it is necessary to evaluate mathematics teachers' practical situations. Based on these findings, the study emphasizes the importance of evaluating mathematics teachers' practical situations before implementing TPACK development programs. This evaluation can help identify the specific training needs of different groups of mathematics teachers and guide the development of differentiated TPACK training programs that are tailored to meet those needs. These programs should focus on improving mathematics teachers' technology-related knowledge, including their TK, TPK, TCK, and TPACK, as well as their non-technology-related knowledge, such as CK and PCK. By providing differentiated TPACK training programs, teacher educators can help mathematics teachers integrate digital technologies into their classroom teaching more effectively, which could ultimately improve student learning outcomes.

Implications

Based on the discussion above, the implication could be associated with two aspects. From a technology-related perspective, most mathematics teachers are willing to adopt new approaches, fresh perspectives, and digital technologies (e.g., Seewo interactive whiteboard, DingTalk, and mathematics software) during the post-pandemic period in their classroom teaching in this primary school. Thus, policymakers should invest in providing digital technologies and infrastructure in schools to facilitate technology integration in primary mathematics education. This could include providing access to interactive whiteboards, mathematics software, and online platforms that support remote and hybrid learning models.

Also, policymakers should review and revise primary mathematics teacher education curricula to ensure that mathematics teachers receive adequate training and support in developing their technology-related competencies. This could involve introducing new courses or updating existing ones to include training in using digital technologies in teaching mathematics. Also, during post-pandemic period, mathematics teachers still lack technology-related capacities such as TK, TCK, PCK, and TPACK. These studies suggest that there is a need for ongoing professional development to improve teachers' technology-related capacities, which could potentially include targeted TPACK development programs (Tondeur et al., 2012). Hence, it is evident that teacher education should focus more on developing mathematics teachers' technology-related competencies during post-pandemic period.

Paying more attention to technology-related competencies does not mean other dimensions of TPACK framework are insignificant. Therefore, there also are three implications from a non-technology perspective. First, the study found that young mathematics teachers with zero-five years of teaching experience require more support in improving their TPACK, particularly in areas of CK and PCK. Second, the analysis did not reveal any significant gender or teaching grade differences. Based on these findings, the paper suggests that TPACK development programs for mathematics teachers should be tailored to their specific training needs rather than a one-size-fits-all approach. This is in line with the argument put forth by (Niess et al., 2009). For example, it is necessary to design TPACK development programs for young teachers to advance their PK and PCK (Hofer & Grandgenett, 2012). Third, experienced mathematics teachers need more support and help from TPACK development programs to improve their technology-related abilities such as TK, TCK and TPK (Ertmer et al., 2012; Koh et al., 2010). By doing so, mathematics teachers can be better equipped to integrate ICT effectively in their classroom teaching and enhance student learning outcomes.

Limitation and Future Research

There are three limitations to this research project. First, the sample size is small, thus triggering the limited generalization of the results. Hence, the conclusion concerning the relationship between mathematics teachers' demographic factors (gender, teaching experience and teaching grade) and TPACK needs more participants to verify its universality and reliability. Therefore, future studies can recruit more participants to increase the sample size. This can improve the statistical power of the analysis and enhance the generalizability of the findings (Cohen et al., 2018). Second, the study relied on self-reported data, probably subject to social desirability bias. Participants may have responded in a way; they believed to be more socially acceptable rather than their actual attitudes and beliefs. A mixed-methods approach that combines quantitative and qualitative data could provide a more comprehensive understanding of the research problem. Therefore, further research could focus on the development of TPACK measurement. To obtain a more accurate and authentic understanding of mathematics teachers' TPACK, an innovative hybrid measurement method that incorporates both subjective and objective approaches should be developed. Third, the instrument used in this study did not use CFA to assess its construct validity due to the small sample size. Byrne (2016) mentioned that CFA is a valuable technique that can help researchers to test their theoretical models, assess construct validity, and improve reliability and precision of their measures.

Hence, future studies can recruit more participants and conduct CFA on their instruments to evaluate the construct validity based on different contexts. Additionally, this study lacks evidence to explain what reasons led to the positive relationship between mathematics teachers' TPACK and their attitudes towards ICT integration in classroom teaching and why the correlation coefficient is low. It seems that some non-TPACK factors influenced the mathematics teachers' attitudes toward ICT integration. As a result, future research could explore the relationships between TPACK and attitudes while examining other potential factors that could affect primary mathematics teachers' attitudes towards integrating ICT, such as policy involvement, traditional cultural influences, and experiences with large-scale online teaching.

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APPENDIX A: MATHEMATICS TEACHERS' TPACK & ATTITUDES TOWARD ICT INTEGRATION QUESTIONNAIRE

Part One: Demographic Information

1. 性别 (Gender)
   - 女 (Female)
   - 男 (Male)
   - 非男女性别/性别多样 (Non-binary/gender diverse)
   - 无答案（Prefer not to say）
2. 任教年级 (Teaching grade)
   - ☐ 一年级 (Grade one)
   - ☐ 二年级 (Grade two)
   - ☐ 三年级 (Grade three)
   - ☐ 四年级 (Grade four)
   - ☐ 五年级 (Grade five)
   - ☐ 六年级 (Grade six)
3. 任教年限 (Years of teaching experience)
   - 0-5 年 (Years)
   - 6-10 年 (Years)
   - 11-15 年 (Years)
   - 15 年以上 (Above 15 years)

Part Two: TPACK Scale

Survey of teachers' knowledge of teaching and technology (Schmidt et al., 2009)

Technological knowledge (TK) 信息技术知识

4. I know how to solve my own technical problems (e.g., teaching software cannot be used normally, PPT needs to insert video animation and so on). 当我遇到信息技术问题时, (如: 教学软件不能正常使用, PPT需要插入视频动画等等), 我能解决.
   - 强烈不认同 （Strongly disagree）
   - 不认同 （Disagree）
   - 既不认同也不反对 （Neither agree nor disagree）
   - 认同 （Agree）
   - 强烈认同 （strongly agree）
5. I can learn technology easily. 我可以很容易地学习信息技术.
   - 强烈不认同 （Strongly disagree）
   - 不认同 （Disagree）
   - 既不认同也不反对 （Neither agree nor disagree）
   - 认同 （Agree）
   - 强烈认同 （Strongly agree）
6. I keep up with important new technologies. 我能紧跟重要的信息技术发展脚步.
   - 强烈不认同 （Strongly disagree）
   - 不认同 （Disagree）
   - 既不认同也不反对 （Neither agree nor disagree）
   - 认同 （Agree）
   - 强烈认同 （Strongly agree）

7. I frequently play around with the technology (e.g., learning different functions on DingTalk). 我经常使用信息技术 (例如: 研究钉钉上不同的功能).
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
8. I know about a lot of different technologies. 我了解很多不同的信息技术.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
9. I have the technical skills I need to use technology. 我拥有使用信息技术所需的基本技能.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
10. I have had sufficient opportunities to work with different technologies. 我有足够的机会使用不同的信息技.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）

Content knowledge (CK) 学科知识

11. I have sufficient knowledge about mathematics (e.g., mathematics concepts, methods, principles, knowledge of mathematical history, etc). 我有足够的数学知识 (数学概念, 方法, 原理, 数学史知识等).
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
12. I can use a mathematical way of thinking. 我可以用数学方式去思考问题.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
13. I have various ways and strategies of developing understanding of mathematics. 在学习数学知识方面我有各种方法和策略.

- 强烈不认同 （Strongly disagree）
- 不认同 （Disagree）
- 既不认同也不反对 （Neither agree nor disagree）
- 认同 （Agree）
- 强烈认同 （Strongly agree）

Pedagogical knowledge (PK) 教学法知识

14. I know how to assess student performance in a classroom. 我知道如何在课堂上评价学生的表现.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
15. I can adapt my teaching based upon what students currently understand or do not understand. 我可以根据学生目前欠缺的知识或掌握的知识来调整我的教学.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
16. I can adapt my teaching style to different learners. 我可以调整我的教学风格以适应不同的学习者.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
17. I can assess student learning in multiple ways. 我可以用多种方式评估学生的学习情况.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
18. I can use a wide range of teaching approaches in a classroom setting. 我可以在课堂上使用各种各样的教学方法.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
19. I am familiar with common student understandings and misconceptions. 我熟悉学生在学习中常犯的错误, 也了解学生在学习中的知识重点与难点.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）

- 既不认同也不反对 （Neither agree nor disagree）
- 认同 （Agree）
- 强烈认同 （Strongly agree）

20. I know how to organize and maintain classroom management. 我知道如何管理课堂和维持课堂秩序.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）

Pedagogical content knowledge (PCK)学科教学知识

21. I can select effective teaching approaches to guide student thinking and learning in mathematics. 我能选择有效的教学方法来拓展学生的数学思维能力, 提高学生的数学学习效率.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
22. I can help my students to understand the content knowledge of mathematics through various ways without using technology. 我能在不使用信息技术的情况下, 通过多种方式帮助我的学生理解数学知识.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
23. I can engage students in solving real world problems related to mathematics without using technology. 我能在不使用信息技术的情况下, 鼓励并帮助学生解决生活中的数学问题.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
24. I can facilitate a meaningful discussion about the mathematics content students are learning without using technology. 我能在不使用信息技术的情况下, 有效组织学生对正在学习的数学内容进行有意义的讨论.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）

Technological content knowledge (TCK)整合信息技术的学科内容知识

25. I know about technologies that I can use for understanding and doing mathematics (e.g., Sketchpad, Excel, mathematics resources in Seewo interactive whiteboard). 我了解可以用来帮助理解数学知识的信息技术（例: 几何画板，Excel, 希沃里面的数学资源等等).

- 强烈不认同 （Strongly disagree）
- 不认同 （Disagree）
- 既不认同也不反对 （Neither agree nor disagree）
- 认同 （Agree）
- 强烈认同 （Strongly agree）

26. I can utilize ICT (e.g., Seewo interactive whiteboard, PPT, and DingTalk) to demonstrate mathematics knowledge and concepts. 我能使用信息技术（例如: 希沃电子白板, PPT, 钉钉等）呈现数学知识和概念.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
27. I know the technology needed for doing educational research (e.g., Smart Education of China and CNKI). 我知道做教育研究需要的信息技术（例如: 国家智慧教育公共服务平台、知网).
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
28. I am able to use technologies to solve real world problems. 我能够使用信息技术来解决现实世界的问题.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）

Technological pedagogical knowledge (TPK)整合信息技术的教学法知识

29. I can choose technologies that enhance the teaching approaches for a lesson. 我能利用信息技术优化我的教学方法.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
30. I can choose technologies that enhance students' learning for a lesson. 我能利用信息技术为课堂服务, 提高学生的学习能力.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
31. My teacher education program has caused me to think more deeply about how technology could influence the teaching approaches I use in my classroom. 教师培训让我更深入地思考信息技术将如何影响我的教学方法

- 强烈不认同 （Strongly disagree）
- 不认同 （Disagree）
- 既不认同也不反对 （Neither agree nor disagree）
- 认同 （Agree）
- 强烈认同 （Strongly agree）

32. I am thinking critically about how to use technology in my classroom. 我不断深入地、批判性地思考如何在课堂上使用信息技术.

- 强烈不认同 （Strongly disagree）
- 不认同 （Disagree）
- 既不认同也不反对 （Neither agree nor disagree）
- 认同 （Agree）
- 强烈认同 （Strongly agree）

33. I can adapt the use of the technologies that I am learning about to different teaching activities. 我能将我学习的信息技术应用到不同的教学活动中.

- 强烈不认同 （Strongly disagree）
- 不认同 （Disagree）
- 既不认同也不反对 （Neither agree nor disagree）
- 认同 （Agree）
- 强烈认同 （Strongly agree）

Technological pedagogical content knowledge (TPACK) 整合信息技术的学科教学知识

34. I can teach lessons that appropriately combine mathematics, technologies, and teaching approaches. 我能在数学课堂上恰当地整合信息技术, 数学知识和教学方法.

- 强烈不认同 （Strongly disagree）
- 不认同 （Disagree）
- 既不认同也不反对 （Neither agree nor disagree）
- 认同 （Agree）
- 强烈认同 （Strongly agree）

35. I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn. 我能够在课堂上通过整合信息技术来丰富我的教学内容, 改善教学方式和优化学生的学习内容.

- 强烈不认同 （Strongly disagree）
- 不认同 （Disagree）
- 既不认同也不反对 （Neither agree nor disagree）
- 认同 （Agree）
- 强烈认同 （Strongly agree）

36. I can provide leadership in helping others to coordinate the use of content, technologies, and teaching approaches at my school and/or district. 我能够帮助我校的教师整合信息技术到教育教学中.

- 强烈不认同 （Strongly disagree）
- 不认同 （Disagree）
- 既不认同也不反对 （Neither agree nor disagree）
- 认同 （Agree）
- 强烈认同 （Strongly agree）

37. I can choose technologies that enhance the content for a lesson. 我能够利用合适的信息技术来拓展课堂教学内容.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
38. I can formulate in-depth discussion topics about the mathematics content and facilitate students' online collaboration with appropriate tools (e.g., DingTalk, Wechat, & TencentMeeting). 我能制定需要深入讨论的数学学习内容, 并通过网络工具（例如: 钉钉, 微信, 腾讯会议) 激励学生利用信息技术在线合作学习.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
39. I can set authentic problems related to mathematics topics and present them through the computers to engage my students. 我能设置与数学主题相关的问题, 并通过信息技术呈现出来, 吸引学生参与数学学习.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
40. I can design student-centred learning that integrates knowledge of mathematics, technologies, and pedagogies. 我能整合学科知识和信息技术来设计以学生为中心的数学课堂.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）

Part Three: ICT Attitude

Attitudes toward computers in education scale (Braak, 2001)

Attitude toward ICT integration:

41. The computer provides opportunity for improving the learning performance. 信息技术的使用为提高学生学习成绩提供了帮助.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
42. The efficiency of the learning process is increased through the use of computers. 使用信息技术能提高学生的学习效率.
    - 强烈不认同 （Strongly disagree）

- 不认同 （Disagree）
- 既不认同也不反对 （Neither agree nor disagree）
- 认同 （Agree）
- 强烈认同 （Strongly agree）

43. The computer increases the level of creativity of students. 电脑提高了学生的创造力水平.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
44. The computer used as a learning tool, increases student motivation. 电脑作为一种学习工具，增加了学生的学习动力.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
45. The pre-service teacher should be provided with strong computer skills and practice during his/her training. 在职教师应具备较强的信息技术能力, 并不断的进行更新和学习信息技术.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
46. Students with learning difficulties can strongly benefit from the didactic possibilities which the use of computers entail. 教师可以通过整合信息技术在教育教学中来提高学困生的学业成就.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
47. Computer knowledge and practical experience should be more integrated in the curriculum. 信息技术知识和实践经验应该更多地整合在课程中.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
48. The functioning of a computer is an important object of study for primary school students. 电脑的使用是小学生学习的一个重要目标.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）

- 既不认同也不反对 （Neither agree nor disagree）
- 认同 （Agree）
- 强烈认同 （Strongly agree）

49. The use of computer helps students better understand geometric concepts. 使用电脑可以帮助学生更好地理解几何概念.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
50. Computers can help the teacher to apply differentiation among the students. 电脑的使用能帮助教师对学生进行因材施教.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
51. It is essential that children start getting acquainted with practical knowledge of computers in primary school. 孩子们从小学开始熟悉信息技术的实用性知识很重要.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）
52. The direction of modern science education is impossible without the introduction of the computer in the learning process. 现代科学教育的方向离不开信息技术在学习过程中的使用.
    - 强烈不认同 （Strongly disagree）
    - 不认同 （Disagree）
    - 既不认同也不反对 （Neither agree nor disagree）
    - 认同 （Agree）
    - 强烈认同 （Strongly agree）