MODESTUM EURASIA Journal of Mathematics, Science and Technology Education, 2023, 19(11), em2350
ISSN:1305-8223 (online)
OPEN ACCESS Research Paper https://doi.org/10.29333/ejmste/13671

Development and validation of the secondary mathematics teachers' TPACK scale: A study in the Chinese context

Mao Li [1*], Abdul Qawi Noori [2], Yanxi Li [1]

[1] School of Curriculum, Teaching and Inclusion, Faculty of Education, Monash University, Melbourne, AUSTRALIA
[2] School of Education, Culture and Society, Faculty of Education, Monash University, Melbourne, AUSTRALIA

Received 14 July 2023 ▪ Accepted 07 September 2023

Abstract

This study aimed to develop and validate the secondary mathematics teachers' technological pedagogical and content knowledge (TPACK) scale (SMTTS) to assess the knowledge domains of TPACK framework among secondary mathematics teachers in China. SMTTS was designed to be subject-oriented and culturally relevant, addressing the specific needs and context of mathematics education in China. Data were collected using a web-based questionnaire from secondary mathematics teachers in Chongqing Jiulongpo District. Exploratory and confirmatory factor analyses were conducted to assess the reliability and validity of the scale. The findings demonstrated that SMTTS exhibited strong reliability and validity, supporting its use as a robust measurement tool for assessing secondary mathematics teachers' TPACK. The scale demonstrated good psychometric properties, including satisfactory factor loadings, internal consistency, and model fit indices. The development of SMTTS contributes to the field by providing a precise and reliable instrument that can inform the design of targeted professional development programs and guide policy decisions regarding technology integration in mathematics education. This study has theoretical and practical implications. SMTTS addresses the need for a subject-specific and culturally relevant assessment tool for measuring TPACK in mathematics education. It acknowledges mathematics teachers' unique challenges in integrating digital technologies into their instructional practices. The scale's development and validation process incorporated considerations of the Chinese educational context, enhancing its relevance for practitioners and researchers in China. SMTTS can facilitate the identification of areas for improvement in teachers' TPACK and guide the implementation of tailored interventions and support initiatives.

Keywords: secondary mathematics education, TPACK, mathematics teachers, scale development, Chinese context

INTRODUCTION

Over the past two decades, digital technology has come to be widely used in mathematics education. During this period, with the increasing popularization of computers, the Internet and mobile devices in education, mathematics educators began adopting new technological means (Hoyles, 2018). For example, teachers are now able to use mathematics software to demonstrate complex mathematical concepts (Martinovic & Karadag, 2012), communicate and interact with students through online courses, discussions, and social media (Mella-Norambuena et al., 2021; Noori et al., 2022). In addition, many schools are starting to use advanced equipment and tools such as interactive whiteboards (Shi et al., 2020), electronic classrooms, and digital textbooks to enhance student's learning effectiveness and interest (Rezat, 2021). Particularly, in recent years, the integration of artificial intelligence (AI) into mathematics education has had a profound impact on the teaching and learning of mathematics (Wardat et al., 2023)

Using digital technology in classroom teaching became more crucial during the post-pandemic era (Noori, 2021). In mainland China, the mathematics curriculum proposes that students should be able to use

✉ mao.li@monash.edu **(*Correspondence)** ✉ Abdul.noori@monash.edu ✉ Yanxi.li@monash.edu

Contribution to the literature

- This study addressed the gap in the literature by developing a subject-oriented and culturally relevant TPACK scale specifically for secondary mathematics teachers in China. This scale offers a precise assessment tool tailored to mathematics teachers' unique needs and challenges in integrating digital technologies.
- Moreover, the study follows a rigorous validation process, including face validity, exploratory and confirmatory factor analyses, enhancing the reliability and validity of the scale. This robust methodology strengthens the confidence in the measurement tool and contributes to the methodological advancements in TPACK research.
- Lastly, the findings have practical implications for professional development programs and policy decisions, providing valuable insights into secondary mathematics teachers' TPACK knowledge domains and guiding the improvement of technology integration in mathematics education.

information and communication technologies (ICT) to study and research the subject; teachers should also master the methods and skills of using digital technology to teach mathematics (Gao, 2021). At the same time, the mathematics curriculum encourages teachers to use digital technology more flexibly, creatively design and carry out teaching activities and enhance teaching effectiveness and students' interest in learning (Wang et al., 2017). Under the guidance of the mathematics curriculum, many Chinese teachers have begun to explore how to use ICT to improve the quality of their mathematics teaching (Yao & Zhao, 2022). The Chinese government also attaches great importance to applying digital technology in education. Since 2000, the Chinese government has invested substantial money and resources to promote the application and development of digital technology in education (Zhang et al., 2010). In 2019, the Chinese government launched 'the opinions on the implementation of the national primary and secondary school teachers' information technology application ability enhancement project 2.0' to further enhance the digital technology integration ability of primary and secondary school teachers nationwide and promote the development and application of digital education (Ministry of Education of the People's Republic of China, 2019). In addition, the government has set up some digital education resource libraries, including online courses, learning materials and teaching tools, to support the learning and teaching of teachers and students. Through these policies and actions, it is evident that the Chinese government is committed to integrating digital technology into the education system and is taking steps to improve the digital technology integration of secondary mathematics teachers nationwide.

Integrating digital technology into teaching mathematics indeed presents several challenges for teachers, despite the recognition of its significance by the government and educators. Lack of ICT capacity is one of the main challenges of integrating digital technology (Bingimlas, 2009). Many mathematics teachers may lack sufficient technical skills to be flexible in using digital technology to support their classroom teaching (Drijvers, 2015). For example, teachers may use interactive whiteboards for classroom instruction. However, they lack the adequate knowledge to apply the link screen board effectively to support classroom teaching, which hinders them from presenting the mathematics content to students appropriately (De Vita et al., 2018). Hamad et al. (2022) contended that the integration also can be negatively influenced by vast curriculum content and lack of time. They believed that in order to facilitate successful integration, it is essential to consider the time constraints of educators and design tools and interventions that align with the existing curriculum and do not overwhelm teachers with additional content or complexity (Hamad et al., 2022). Moreover, incorporating digital technology into mathematics classrooms was hindered by a lack of financing, digital technological resources, and technical gaps between teachers and pupils (Drijvers et al., 2010). However, the most emphasized is the dearth of technological pedagogical and content knowledge (TPACK) among mathematics teachers (Mailizar et al., 2021; Patahuddin et al., 2016; Rakes et al., 2022). In order to address the challenges faced by teachers in integrating digital technology into mathematics education, it is essential to recognize the importance of technology integration and provide teachers with effective professional development and support. Therefore, developing and employing assessment tools to measure mathematics teachers' TPACK is of utmost importance. Such instruments play a critical role in identifying specific areas, where teachers require additional support, training and evaluating the effectiveness of technology integration initiatives (Niess et al., 2009; Schmidt et al., 2009). By assessing teachers' TPACK, educators and policymakers gain valuable insights into individual teachers' strengths and areas for improvement, enabling the customization of support and training programs.

Moreover, these assessments inform curriculum and policy decisions, facilitating the development of guidelines, standards, and instructional materials that

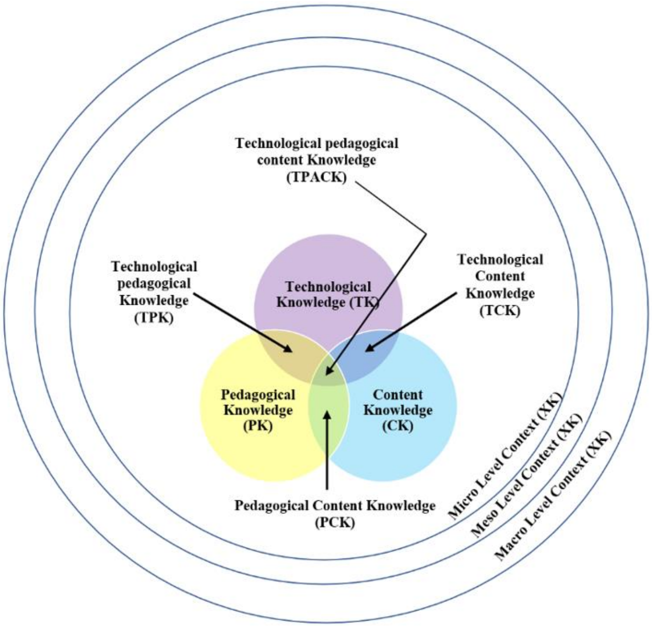

Figure 1. Components of TPACK framework (Mishra & Koehler, 2006; Porras-Hernández & Salinas-Amescua, 2013)

effectively enhance teachers' utilization of digital technology to enrich mathematics education. Based on the discussion above, developing survey instruments for the measurement of mathematics teachers' TPACK is therefore essential. It can help identify areas, where mathematics teachers may need additional support and provide insights into their beliefs and attitudes towards technology in the classroom (Niess et al., 2009).

However, a notable concern is the lack of validated TPACK instruments specifically designed for secondary mathematics teachers, particularly in mainland China (Scott, 2021). This limitation hampers researchers' ability to accurately measure the effectiveness of technology integration in mathematics classrooms and identify specific areas, where additional support and training may be needed.

To address this gap, developing and validating survey instruments tailored explicitly to the context of secondary mathematics teachers in mainland China becomes necessary. These instruments should effectively capture the knowledge domains outlined in TPACK framework. By doing so, researchers and educators can obtain accurate data to inform professional development initiatives and support teachers' technology integration efforts. To investigate and address these needs, the authors of the research focused on two researcher questions:

1. Is the scale developed in the study reliable to measure secondary mathematics teachers' knowledge domains of TPACK framework?
2. Is the scale developed in the study valid to measure secondary mathematics teachers' knowledge domains of TPACK framework?

LITERATURE REVIEW

Theoretical Framework

TPACK model, which is based on the concept of pedagogical content knowledge (PCK), was first presented by Shulman (1986) and has been widely acknowledged as a critical competency for 21st-century teachers (Mishra & Koehler, 2006; Voogt et al., 2013; Willermark, 2018). Numerous educational research has utilized TPACK as a core theoretical framework to study the knowledge that both pre-service and in-service teachers require in order to integrate digital technology into teaching and learning effectively (Scott, 2021). Many researchers believe that TPACK framework defines the knowledge that teachers must have to integrate digital technology into their teaching practice effectively and enhance their knowledge (Harris & Hofer, 2011; Koh et al., 2010; Li, 2023; Voogt et al., 2013).

Within TPACK, the interaction of three essential knowledge domains, which are content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK), results in seven TPACK components (**Figure 1**).

Koehler et al. (2013) define these seven components (**Table 1**). However, there is ongoing debate about the validity of TPACK framework, even as it gains popularity (Angeli et al., 2016; Niess, 2011). Graham (2011), for instance, asserted that TPACK framework lacks a clear definition of technological pedagogical knowledge (TPK), technological content knowledge (TCK), PCK, and TPACK, especially contextual knowledge (Porras-Hernández & Salinas-Amescua, 2013; Rosenberg & Koehler, 2015).

In order to enhance this theoretical framework, Porras-Hernández and Salinas-Amescua (2013) identified three contextual levels (micro, meso, and macro) to redefine contextual knowledge (XK). The micro, meso, and macro levels are intended to provide a deeper and more nuanced understanding of the contextual factors that impact technology integration in education:

1. **Micro:** the contextual factors associated with classroom teaching and learning (e.g., teachers' understanding of classroom norms and the availability of digital devices).
2. **Meso:** the contextual factors linked to school and community support, including school culture and system, leadership support, educational infrastructure, and communities.
3. **Macro:** The contextual factors include national and international policies, culture, the economy, and educational background (e.g., national curriculum standards and national education policy).

Table 1. Components of TPACK framework

No	Component	Definition of component
1	CK	This refers to CK teachers required to teach a specific subject area. It is comprehending a given subject's fundamental concepts, principles, and theories.
2	PK	PK relates to the instructional design and delivery skills teachers must possess. It requires an awareness of teaching and learning principles and practices.
3	TK	TK refers to the expertise required for teachers to utilize technology efficiently. It requires technical knowledge of hardware, software, and digital tools.
4	PCK	PCK is comparable to Shulman's (1986) definition of pedagogical knowledge as the knowledge and skills of pedagogy to teach specific content.
5	TCK	TCK refers to teachers' knowledge to teach their subject utilising technology effectively. It entails understanding how technology can enhance students' learning of a specific subject area.
6	TPK	TPK relates to knowledge required for teachers to plan & deliver successful technology-based instruction. It entails knowing how to utilize digital technology to support pedagogical methods & instructional strategies.
7	TPACK	TPACK refers to the knowledge teachers need to integrate technology into their content area-specific teaching practices effectively. It entails knowing how technology can support pedagogical approaches and instructional strategies for a particular subject.
8	XK	XK has been defined as knowledge that helps teachers be aware of factors influencing use of digital technology in teaching & learning from perspective of schools, districts, states, or national policy.

Accordingly, Mishra (2019) added the eighth factor XK into TPACK framework in 2019 to better explain teachers' knowledge to integrate digital technology into teaching and learning. Based on the discussion above, the eight components are defined in **Table 1**.

Development & Evaluation of TPACK Surveys: Assessing Validity & Reliability

It is worth noting that since the introduction of TPACK framework, a few TPACK surveys have been developed. The most widely used TPACK instrument is the "survey of preservice teachers' knowledge of teaching and technology" developed by Schmidt et al. (2009). The 58-item survey assessed seven constructs of primary school teachers' TPACK in relation to the subject areas of mathematics, social studies, science, and literacy. Cronbach's alpha ranged between .75 and .92 for the pilot test, which involved 124 American Preservice teachers. Factor analyses were conducted on each construct, and the validity and reliability of the instrument seemed promising. Based on the instrument designed by Schmidt et al. (2009), many TPACK instruments were then developed by other researchers for specific contexts to measure teachers' knowledge of integrating digital technology in classroom teaching (Scott, 2021).

One of the more representative TPACK instruments was developed by Sahin (2011). A systematic and step-by-step approach was followed to ensure the validity and reliability of the scale. The survey was tested with pre-service teachers, with a pool of 60 items reduced to 47 items after expert evaluation. Exploratory factor analysis (EFA) was conducted to examine construct validity and factor structure, and the results showed that the survey items for each subscale measured each variable successfully. Internal consistency and item-total correlations were calculated, indicating high levels of internal consistency and discriminant validity. However, the survey was only tested with a sample of pre-service mathematics teachers, so whether the results could be generalized to in-service mathematics teachers was unclear. Also, Sahin (2011) was conducted in the educational context of Turkey, and the findings may not be applicable to other contexts. When focusing TPACK instrument designed and used in the Asia context, the survey developed by Chai et al. (2013) plays a significant role in this context. In their study, Chai et al. (2013) investigated 550 preservice teachers from teacher education institutes in China, Hong Kong, Singapore, and Taiwan. The participants had an average age of 23.5, with 68.9% of them being female. The primary objective of the study was to assess the preservice teachers' TPACK using a 36-item questionnaire. This questionnaire was adapted from the study conducted by Schmidt et al. (2009) but included certain modifications. To establish the validity and reliability of the questionnaire, confirmatory factor analysis (CFA) was employed. Through this analysis, seven factors were identified: CK, PCK, PK, TPCK, TCK, TPK, and TK. The reliability coefficients for these factors ranged from .88 to .92, indicating strong internal consistency. The survey developed by Chai et al. (2013) has proven to be a valid and reliable instrument for measuring TPACK of preservice teachers. It specifically caters to the Asian context and has been utilized to gain insights into TPACK development of preservice teachers (Chai et al., 2019; Koh et al., 2016; Xiong et al., 2020).

When investigating teachers' knowledge of integrating digital technologies in classroom teaching, researchers have devoted extensive attention to TPACK framework, employing survey instruments and quantitative analyses to explore teachers' TPACK. Throughout these studies, some TPACK instruments, such as Schmidt et al. (2009) and Chai et al. (2013), have garnered particular interest and varying degrees of success in their application (Scott, 2021). However, despite the advancements made in TPACK research, it is essential to acknowledge that there are still limitations in the existing TPACK instruments. One notable limitation is the lack of consideration for contextual factors in their scales (Harris & Hofer, 2011; Scott, 2021). Contextual factors are crucial in shaping teachers' TPACK knowledge and practices (Mishra, 2019). Teachers operate within diverse educational contexts that vary in subject areas, available technological tools, and their schools' socio-cultural and institutional settings. Different subject areas may require specific technological tools and resources to integrate digital technologies into teaching practices effectively. Additionally, the accessibility and availability of these tools can vary across different schools and classrooms. Furthermore, teachers' cultural backgrounds, socioeconomic factors, and the institutional support they receive also influence their TPACK development and integration (Rosenberg & Koehler, 2015). Therefore, it is crucial for TPACK instruments to consider these contextual factors to provide a comprehensive and accurate assessment of teachers' TPACK knowledge and practices. By incorporating a contextual construct, TPACK instruments can capture teachers' unique challenges and opportunities in their specific educational environments. This would allow for a more nuanced understanding of how teachers integrate digital technologies into their subject-specific instruction, considering the constraints and affordances of their context. Furthermore, the generalizability of existing TPACK instruments to different populations and contexts remains a concern. These instruments have been developed and validated with specific populations, such as preservice mathematics teachers (Sahin, 2011). Consequently, there is a need for further research to develop and validate TPACK instruments that can be applied across various teacher populations and educational contexts. This TPACK instrument would ensure that the assessment of teachers' TPACK knowledge is not limited to specific groups but can be used more widely to inform professional development and policy initiatives.

In conclusion, developing TPACK instruments that incorporate a contextual construct is crucial to account for the diverse educational environments in which teachers work. By addressing this limitation, researchers can better understand teachers' TPACK knowledge and practices, enabling them to provide more effective support for integrating digital technologies in classroom teaching. This research endeavor holds the potential to enhance teacher education and improve technology integration in educational settings. By recognizing the significance of context in TPACK assessment, educators and policymakers can work together to foster an environment that empowers teachers to utilize digital technologies for enhanced teaching and learning outcomes effectively. Ultimately, this holistic approach will contribute to advancing education and preparing students for a technology-driven future.

METHOD

Research Design

The study aimed to design a valid and reliable TPACK instrument specifically for secondary mathematics teachers in the Chinese context. To accomplish this, the researchers selected two previously validated instruments, one by Chai et al. (2013) and another by Schmidt et al. (2009), which serve as prototypes for modification. Schmidt et al. (2009) instrument, widely used in various contexts, and Chai et al. (2013) instrument, culturally relevant to Chinese mathematics teachers, provide a strong foundation for developing the new TPACK instrument. The selected instruments were then modified to align with the specific requirements and context of secondary mathematics teachers in China. The modifications took cultural relevance into consideration and incorporated the XK construct, encompassing technology, pedagogy, content, and the specific teaching context. This integration ensured a comprehensive assessment of mathematics teachers' TPACK in the Chinese educational landscape. Using the modified prototypes and the XK construct, the researchers successfully developed a new TPACK instrument tailored to measure TPACK of secondary mathematics teachers in the Chinese context. This instrument is a valuable tool to evaluate teachers' proficiency in integrating technology effectively within their mathematics instruction.

Subsequently, the researchers administered the newly developed TPACK instrument to a representative sample of secondary mathematics teachers in China. The sample size was carefully determined to ensure the reliability and validity of the instrument's results. The collected data were then subjected to rigorous statistical analysis to assess the reliability and validity of TPACK instrument. Internal consistency measures, such as Cronbach's alpha, were employed to evaluate the reliability of the instrument's items. Additionally, EFA and CFA were utilized to assess the validity of the instrument. By examining the internal consistency, stability, and factor structure of TPACK instrument, the researchers ascertained its reliability and validity. These assessments provide valuable insights into the instrument's ability to measure mathematics teachers' TPACK accurately and consistently. Therefore, the study's research design involved selecting, modifying, and developing a TPACK instrument based on established prototypes, collecting data from a representative sample, and conducting rigorous statistical analysis to evaluate the instrument's reliability

Table 2. Participants by educational background

		Junior college	Bachelor's degree	Master's degree	Doctor degree	Total
Degree in mathematics education	Yes	44	155	76	17	292
	No	42	75	41	1	159
Total		86	230	117	18	451

and validity. This comprehensive approach ensures the creation of a robust TPACK instrument suitable for assessing mathematics teachers' TPACK in the Chinese context.

Instrument Design

The instrument includes eight constructs (CK, PK, TK, PCK, TCK, TPK, TPACK, and XK) to measure secondary mathematics teachers' TPACK. Notably, the XK construct is new in this TPACK instrument. As this study is based on mainland China's secondary mathematics education context, which is different from other countries, when redesigning items, we introduced relevant examples of different items to help secondary mathematics teachers comprehensively understand the meaning of the items. Also, we used mathematics CK instead of other subjects to make the items more specific in the mathematics educational domain. Here is an item example concerning the construct of TPACK: "I can design inquiry activities to guide students to make sense of the mathematics CK with appropriate technological tools (e.g., I can help students use an iPad to learn the surface area of a cuboid in a group discussion)". This item initially stems from Chai et al. (2013). Drawing inspiration from Chai et al. (2013), the authors have enriched the item by adding a specific example that illustrates the intended meaning and application. This approach enhances the clarity and comprehensibility of the instrument, allowing participants to understand the item's purpose better and respond accurately. By providing additional examples in **Appendix A**, the authors further enhance the instrument's usefulness and applicability by showcasing a range of scenarios, where technology can be effectively integrated into mathematics instruction. This contribution helps mathematics teachers grasp the practical implications of TPACK construct and enables them to envision specific ways to incorporate technology into their teaching practices.

Participants

The participants in this study were randomly selected from Chongqing Jiulongpo District, representing in-service mathematics teachers from middle schools in southwest China. The research team collaborated with the Chongqing Teacher Education Training Center to distribute a web-based questionnaire via WeChat to secondary mathematics teachers from all middle schools in the district. Approximately, there are 1,500 middle school mathematics teachers in the district. Eventually, 451 teachers completed the questionnaire, resulting in a response rate of approximately 30.1%. The participants comprised 141 females and 310 males. They represented all three grades of middle school education: grade 7 (35.0%), grade 8 (32.2%), and grade 9 (32.8%). Most participants held a bachelor's degree (51.0%), while a small percentage (4%) possessed a PhD degree. Moreover, it is noteworthy that 35.3% of the mathematics teachers had non-mathematics educational backgrounds, while 65.7% had backgrounds in mathematics education (see **Table 2**).

Recruitment

The recruitment process for this study involved collaboration with the Chongqing Teacher Education Training Center to ensure the participation of secondary mathematics teachers from various middle schools in Chongqing Jiulongpo District, located in southwest China. A web-based questionnaire was developed and distributed to potential participants via WeChat, a popular communication platform in China. The research team worked closely with the Chongqing Teacher Education Training Center's administrator to facilitate the questionnaire's distribution. Throughout the recruitment phase, the researchers ensured the anonymity and confidentiality of the participants' information. This process aimed to ensure a representative sample of secondary mathematics teachers from Chongqing Jiulongpo District, thus contributing to the study's validity and generalizability of findings.

Data Collection

The data collection process employed in this study involved the administration of a web-based questionnaire to the secondary mathematics teachers participating in the research. A random sampling method was employed to recruit participants from a population of secondary mathematics teachers in Chongqing Jiulongpo District. The questionnaire was designed to gather comprehensive data on the teachers' knowledge and practices regarding integrating digital technologies in mathematics education. The questionnaire comprised multiple sections and items that explored eight TPACK dimensions: CK, PK, TK, PCK, TCK, TPK, TPACK, and XK. The distribution of the web-based questionnaire was facilitated through the WeChat platform, which ensured accessibility and convenience for the participants. Clear instructions were provided to guide teachers through the questionnaire completion process, and an adequate time frame was allocated for them to respond to all the items accurately. No personal identifying information was collected within the questionnaire to ensure the confidentiality and anonymity of the participants. Strict data security protocols were implemented to safeguard the collected data, limiting access solely to the research team. To increase the response rate, we designed a poster to provide the information to the mathematics teachers, which included the research aim, significance of participation, and participation way (e.g., QR code and questionnaire link). Therefore, the participants could freely and anonymously participate in the survey. Also, the informed consent and explanatory statement were embedded in the web-based questionnaire. The data collection period was set to four weeks, allowing the participants flexibility in completing the questionnaire at their convenience. Prompt reminders were sent to the participants to encourage a high response rate and maximize the data collection process.

Data Analysis

Two software were utilized to analyze the data: statistical package for the social science (SPSS, Version 28) and AMOS (version 27). The data collected from the web-based questionnaire were subjected to rigorous data analysis procedures to examine the reliability and validity of the scale developed in this study to measure secondary mathematics teachers' knowledge domains of TPACK framework. Concerning the reliability of the scale, Cronbach's alpha coefficient was calculated for each dimension of TPACK framework (CK, PK, TK, PCK, TCK, TPK, TPACK, and XK) to determine the internal consistency (Cohen et al., 2018). A high Cronbach's alpha value (typically ≥.70) indicates a high level of internal consistency and reliability (Cohen et al., 2018). Additionally, to evaluate the validity of the scale, EFA and CFA were conducted. EFA was used to explore the underlying factor structure of the scale and determine the number and nature of latent factors representing TPACK dimensions (Ho, 2014). This analysis provided insights into whether the items within each dimension were loading onto the corresponding factors as intended. CFA was then conducted to confirm the factor structure identified through EFA and assess the goodness-of-fit between the observed data and the hypothesized measurement model (Byrne, 2016). Various fit indices, such as the chi-square test, comparative fit index (CFI), Tucker-Lewis index (TLI), and root mean square error of approximation (RMSEA), were considered to evaluate the model fit. A well-fitting model indicated that the scale adequately measures the intended TPACK dimensions.

Additionally, convergent and discriminant validity were examined. Convergent validity was assessed by examining the factor loadings of the items on their respective latent factors, with higher loadings indicating a stronger relationship between the items and the underlying construct. Discriminant validity was assessed by comparing the average variance extracted (AVE) for each construct with the squared correlations between constructs (Byrne, 2016). Finally, the data analysis procedures outlined above provided a comprehensive assessment of the reliability and validity of the scale developed in this study to measure the knowledge domains of TPACK framework among secondary mathematics teachers.

FINDINGS

This section presents the findings from a comprehensive evaluation of the instrument's reliability and validity through various analyses, including face validity assessment, EFA and CFA. The results provide insights into the instrument's effectiveness in measuring the knowledge domains of TPACK framework among secondary mathematics teachers.

Face Validity

Three strategies were implemented to ensure the face validity of TPACK scale in this study: literature review, expert review, and pilot testing (DeVellis, 2017). First, a thorough literature review was conducted, leading to the selection of two widely used and validated TPACK instruments developed by Schmidt et al. (2009) and Chai et al. (2013). These instruments were chosen due to their established reliability and validity, indicating their relevance for measuring secondary mathematics teachers' TPACK. Second, expert reviewers in secondary mathematics education and TPACK framework were invited to evaluate the scale's relevance, clarity, and appropriateness. Their valuable insights and feedback were incorporated to refine the scale and ensure its alignment with the intended construct. Lastly, a pilot test phase was conducted with 65 secondary mathematics teachers who completed TPACK scale. The participants' feedback from the pilot test was carefully analyzed, leading to further refinements to improve the scale's face validity. These iterative refinements based on pilot testing helped enhance the scale's accuracy and appropriateness for measuring secondary mathematics teachers' TPACK knowledge. By employing these three strategies, the study ensures that TPACK scale has undergone rigorous evaluation to establish its face validity, providing confidence in its ability to accurately measure the intended construct (Bryman, 2016).

Exploratory Factor Analysis

EFA can provide evidence for the construct validity of a TPACK scale by examining how well the scale items load onto the identified factors, helping researchers develop or refine theoretical frameworks and scales related to TPACK by providing empirical evidence for the underlying factor structure of the construct (Roni,

Table 3. KMO & Bartlett's test of sphericity

Pilot test		
Kaiser-Meyer-Olkin measure of sampling adequacy		.928
Bartlett's test of sphericity	Approximate Chi-square	9,804.511
	df	703
	Significance	<.01
Formal questionnaire		
Kaiser-Meyer-Olkin measure of sampling adequacy		.916
Bartlett's test of sphericity	Approximate Chi-square	7,804.929
	df	496
	Significance	<.01

Table 4. Item removing explanation

Factors	Items	Reasons for removing
TK	Item 8. I know how to solve my own technical problems (e.g., The computer does not work properly, insert video into PPT).	Factor loading is less than .4.
TK	Item 12. I have sufficient knowledge about mathematics (e.g., mathematical concepts, curriculum, methods, principles, knowledge of mathematical history, etc.).	Based on TPACK theory, this item is not directly related to TK. This item is more associated with CK.
CK	Item 16. I know how to assess student performance in a classroom.	Based on TPACK theory, this item is not directly related to CK. This Item is more associated with PK.
PK	Item 21. I can select effective teaching approaches to guide student thinking and learning in mathematics without using technology.	Based on TPACK theory, this item is not directly related to PK. This item is more related to PCK.
PCK	Item 25. I know about technologies I can use to understand and do mathematics (e.g., Geometer's Sketchpad, Excel, mathematics resources in Seewo interactive whiteboard et al.).	Based on TPACK theory, this item is not directly related to PCK. This item is more associated with TCK.
TPACK	Item 41. I understand what information technology equipment in the classroom can be used in mathematics classroom teaching.	Based on TPACK theory, this item is not directly linked to TPACK. This item is more related to XK.

2021). This method can contribute to the advancement of theory and knowledge in educational technology and instructional design (Cohen et al., 2018). To conduct EFA, Kaiser-Meyer-Olkin (KMO) and Bartlett's test were used to assess the appropriateness of the data for factor analysis (see **Table 3**).

KMO assesses the adequacy of the sample size, and Bartlett's test checks for sufficient intercorrelations among variables (Ho, 2014). In this study, EFA was used two times. The first time was used in the pilot test, and it helped researchers remove six irrelevant items. The second time, EFA was used to verify the structure validity of the new version of secondary mathematics teachers' TPACK scale. Moreover, based on the Eigen values greater than one, the principal components approach was used for factor analysis extraction to determine the number of factors. Also, Promax, which is an oblique rotation method, was used for factor analysis rotation because it allows factor correlation (Roni, 2021). The factor load minimum for each item was determined to be .40 (DeVellis, 2017). The authors conducted EFA for polit test and formal questionnaire based on these criteria.

Pilot Test

SMTTS was initially developed, including eight constructs and 38 items: CK (n=4), PK (n=5), TK (n=4), PCK (n=4), TCK (n=4), TPK (n=6), TPACK (n=6), and XK (n=5). Concerning the pilot test, **Table 3** shows that KMO is .928, and Bartlett's test is significant ($p<.01$). Hence, the data used in the factor analysis was suitable for EFA. After the rotation, eight factors were extracted. The total variance explained was 69.1%, and the factor load values were between .754 and .881 during the pilot test except for one item. The item was removed from SMTTS because its factor loading was less than .40. Also, five more items were deleted from SMTTS because these items were not relevant to the corresponding factors. The reasons are presented in **Table 4**.

After this process, there were 32 items in SMTTS, and the new scale was used for the formal questionnaire.

Formal Questionnaire

In the formal questionnaire, 451 mathematicians participated in this investigation. there were 32 items: CK (n=3), PK (n=4), TK (n=3), PCK (n=3), TCK (n=4), TPK (n=6), TPACK (n=5), and XK (n=4). KMO is .916, and Bartlett's Test was significant ($p< .01$) (see **Table 3**), and the total variance explained was 71.5%. This finding indicated that the data were suitable for factor analysis,

Table 5. Exploratory factor analysis pattern matrix principal component analysis (formal questionnaire)

		Cronbach's alpha	1	2	3	4	5	6	7	8
TPK	A33	.889	.874							
	A31		.863							
	A32		.814							
	A35		.793							
	A30		.777							
	A34		.754							
TPACK	A37	.883		.879						
	A40			.833						
	A36			.799						
	A38			.796						
	A39			.784						
XK	A45	.876			.863					
	A43				.862					
	A44				.859					
	A42				.824					
PK	A18	.863				.859				
	A17					.835				
	A19					.825				
	A20					.816				
TCK	A28	.846					.867			
	A26						.835			
	A29						.802			
	A27						.755			
TK	A9	.853						.886		
	A10							.874		
	A11							.845		
PCK	A23	.828							.892	
	A24								.848	
	A22								.821	
CK	A14	.820								.882
	A13									.845
	A15									.827

and the extracted factors collectively accounted for a significant portion of the variability observed in the data. Also, the principal component analysis extracted eight factors, and the factor loading values were between .754 and .892 (see **Table 5**).

This finding suggested strong associations between the items and the factors, indicating that the items were effective indicators of the underlying constructs represented by the factors. Moreover, the internal consistency of the items of SMTTS was assessed via Cronbach's alpha test, and the Cronbach's alpha coefficient was between .82 and .889, which indicated a high level of internal consistency among the items of SMTTS, according to Cohen et al. (2018) (see **Table 5**). Therefore, based on the finding, it is evident that SMTTS is a reliable instrument to measure secondary mathematics teachers' TPACK.

CFA

By examining the relationships between the items and their respective factors, CFA can provide evidence for the convergent validity (items within the same factor are strongly related) and discriminant validity (that items from different factors have weak correlation) of the instrument (Byrne, 2016). This analysis helps establish that the instrument is measuring distinct constructs as intended. Many fit indexes can be used to determine the adequacy of the model tested in CFA. However, it is crucial to note that no single fit index can provide a definitive answer concerning the validity of a scale (Cetin & Erdogan, 2018; Valtonen et al., 2017). In this study, the researchers assessed the convergent validity based on AVE and composite reliability (CR). Simultaneously, according to Byrne (2016), x^2/df, RMSEA, goodness of fit index (GFI), adjust goodness-of-fit index (AGFI), normed fit index (NFI), CFI, and TLI were used to assess the discriminant validity of SMTTS (see **Table 6**).

Convergent Validity

Evaluating convergent validity is an essential process in the validation process of an instrument measurement, as it provides evidence for the instrument's construct validity and reliability, which enhances the construct's understanding and facilitates comparisons with existing literature (DeVellis, 2017). This study used two formulas

Table 6. SMTTS fit values

Fit indices	Good fit values	Acceptable fit values	SMTTS scale fit values
x^2/df	$.00<x^2/df<3$	$.00<x^2/df<5$	1.295
RMSEA	.00< RMSEA<.05	.05<RMSEA<.10	.026
GFI	.95< GFI<1	.90<GFI<.95	.928
AGFI	.90<AGFI<1	.85<AGFI<.90	.913
NFI	.95<NFI<1	.90<NFI<.95	.929
CFI	.95<CFI<1	.90<CFI<.95	.983
TLI	.95<TLI<1	.90<TLI<.95	.980

Table 7. Convergent validity

	$CR = \frac{\left(\sum_{i=1}^{i} \lambda_i\right)^2}{\left(\sum_{i=1}^{i} \lambda_i\right)^2 + \left(\sum_{i=1}^{i} 1-\lambda_i^2\right)}$	$AVE = \frac{\sum_{i=1}^{k} \lambda_i^2}{k}$
CK	.820	.603
TPACK	.883	.602
XK	.876	.639
TPK	.901	.604
TCK	.847	.580
PCK	.828	.617
PK	.863	.612
TK	.853	.659

(see **Table 7**) to calculate AVE and CR coefficient (Henseler et al., 2015).

As shown in **Table 7**, AVE and CR are reported for each construct. AVE values (from .580 to .659) above the threshold of .50 generally indicate good convergent validity for the instrument (Hair et al., 2010). Meanwhile, all the constructs have CR values ranging from .820 to .901, above the commonly accepted threshold of .70, indicating acceptable to good levels of internal consistency reliability for the instrument (Hair et al., 2010). This finding suggested that the instrument used in the study has acceptable to good levels of internal consistency, confirming the reliability and convergent validity for the assessed constructs (CK, TPACK, XK, TPK, TCK, PCK, PK, and TK) and providing evidence for the soundness of the instrument in measuring the designates constructs in the research study.

Discriminant Validity

Evaluating a scale's discriminant validity is crucial for ensuring accurate measurement of distinct constructs, minimization of methodological bias, enhancement of construct validity, accurate interpretation of study results, and advancing theoretical development (DeVellis, 2017; Hair et al., 2010). It is an essential step in the validation process of measurement scales in research and is widely recognized as an essential aspect of rigorous measurement validation (Byrne, 2016). Based on suggestions from Hair et al. (2010), this study assessed the basis of goodness-of-fit in seven aspects concerning SMTTS scale (x^2/df=1.295, RMSEA=.026, GFI=.928, AGFI=.913, NFI=.929, CFI=.983, and TLI=.980).

Figure 2 presents the loadings of items on their respective subscales, correlations between latent variables, and correlated residuals. These analyses provide insights into the measurement model's performance in relation to the collected data. The reported values of these fit indices in the present study indicate that the measurement model achieved a satisfactory level of fit. This finding suggests that the measurement scales employed in the study effectively captured the intended constructs within the secondary mathematics teachers' knowledge domains of TPACK framework. Also, this finding supports validity of the measurement instrument and indicates its suitability for accurately measuring targeted constructs in the study.

DISCUSSION

Digital technologies have emerged as vital tools in mathematics education during the post-pandemic era (Khong et al., 2023). In the mathematics classroom, many teachers leverage interactive whiteboards to represent mathematical concepts, enhancing student understanding visually (Gonzales & Gonzales, 2021). Additionally, a wide range of mathematics software, the Internet resources, AI, and digital devices are being utilized to enrich the quality of mathematics lessons and facilitate students' learning of mathematical knowledge and skills (Caniglia & Meadows, 2018; Sun et al., 2023). In this contemporary era, characterized by the pervasive influence of digital technologies, the knowledge domains encompassed by teachers' TPACK have gained heightened significance (Scott, 2021). Effective technology integration in mathematics instruction requires teachers to understand the interplay between technology, pedagogy, and CK. TPACK framework enables teachers to navigate the digital landscape and employ technology to optimize mathematics teaching and learning experiences (Schmidt et al., 2009). Therefore, using a subject-oriented TPACK scale to evaluate teachers' knowledge to integrate digital technologies in teaching mathematics becomes crucial in the current era (Li, 2023). This study designed SMTTS to comprehensively measure secondary mathematics teachers' knowledge of integrating digital technologies in classroom teaching to fill the gap. Also, the findings in this study suggest that SMTTS is proven statistically as a reliable and valid scale. Based on the findings, two significant points need to be highlighted.

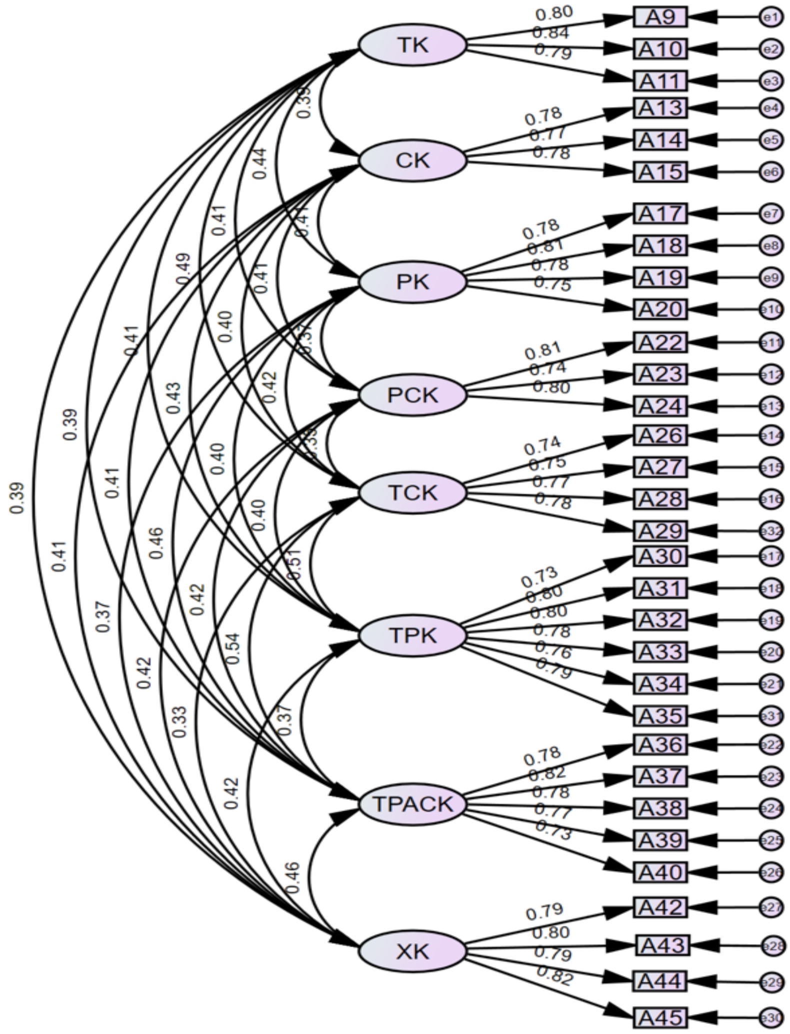

Figure 2. Confirmatory factor analysis result of SMTTS (Source: Authors' own elaboration)

First, some previous TPACK scales have focused on the seven components of TPACK framework to measure mathematics teachers' knowledge of integrating digital technology in classroom teaching (Cetin & Erdogan, 2018; Scott & Nimon, 2020; Su et al., 2017). These components include CK, PK, TK, PCK, TPK, TCK, and TPACK. By assessing these specific components, TPACK scales comprehensively evaluate teachers' proficiency in leveraging technology to enhance their pedagogical practices and content delivery. These TPACK scales provide valuable insights into teachers' knowledge for effective technology integration in classroom teaching (Scott, 2021). With focusing on the seven components of TPACK framework, researchers and educators can identify strengths and weaknesses in teachers' knowledge domains and design targeted professional development programs to enhance their TPACK competencies. However, it is essential to note that TPACK scale developed in this study (SMTTS) addresses the needs of secondary mathematics teachers in mainland China, providing a more tailored and context-specific measurement tool. While previous TPACK scales may encompass the same components, the focus and relevance may differ based on the specific subject area and cultural context. For instance, during the post-pandemic era, various mathematics software, internet resources, and digital devices have been designed specifically for mathematics education in China (Cao et al., 2021). They provide interactive platforms, virtual manipulatives, and online problem-solving environments that enhance students' engagement, understanding, and application of mathematical concepts (Tanu Wijaya, 2020). The authors took this situation into account and designed items in SMTTS that were compatible with the contemporary educational context to accurately measure secondary mathematics teachers' knowledge of integrating digital technology in teaching mathematics. Importantly, SMTTS includes the XK component in the scale to measure how mathematics teachers are familiar with their educational and technological environment. Indeed, teachers' XK plays a significant role in successfully integrating digital technologies in classroom teaching (Ifinedo & Kankaanranta, 2021; Mishra, 2019). Therefore, it can be said that SMTTS offers a more precise and comprehensive assessment of secondary mathematics teachers' TPACK in the Chinese context.

Second, researchers have commonly used the general term technology in the scales for evaluating teachers' TPACK in many studies (Giannakos et al., 2014; Schmidt et al., 2009; Valtonen et al., 2017). This approach encompasses a broader range of digital tools, ICT, and technological resources that can be employed in various subject areas. By adopting these general terms, researchers captured the broader aspects of technology integration across different disciplines and educational contexts. The use of terms like "technologies," "ICT," or "digital tools" allows for flexibility in addressing the common elements of technology integration, regardless of the specific subject matter. While this approach provides a broad understanding of technology integration, it may overlook the unique challenges, practices, and resources specific to particular subject areas, such as mathematics. Mathematics has its own set of tools and software that are specifically designed to support mathematical instruction and problem-solving activities (Alabdulaziz, 2021). These subject-specific resources play a crucial role in enhancing students' mathematical understanding and proficiency, such as GeoGebra and Geometer's Sketchpad (Acikgul & Aslaner, 2020; Zambak & Tyminski, 2019).

Recognizing the importance of subject-specific technology integration, TPACK scale developed in this study (SMTTS) considers the specific digital tools and resources relevant to mathematics education in the Chinese context, such as Geometer's Sketchpad, Excel, and Seewo mathematics software. By focusing on the subject-specific aspects of technology integration, SMTTS provides a more precise assessment of secondary mathematics teachers' TPACK knowledge, addressing the specific challenges and practices unique to secondary mathematics teaching. Additionally, the inclusion of subject-specific items in SMTTS, such as the use of mathematics software and applications for teaching and learning, enhances its relevance and applicability for mathematics teachers. It allows for more accurate measurement of secondary mathematics teachers' TPACK competencies, ensuring that the scale adequately captures the knowledge and skills necessary for effective technology integration in mathematics education. By adopting a subject-oriented approach in the design of TPACK scale, researchers can gather more detailed insights into the specific technology integration practices and challenges faced by mathematics teachers (Li, 2023). SMTTS scale enables a more targeted approach to professional development and support initiatives, helping mathematics teachers enhance their abilities to integrate digital technologies into their instructional practices effectively.

CONCLUSIONS

This study aimed to develop and validate a TPACK scale for measuring the knowledge domains of TPACK framework among secondary mathematics teachers in China. The findings of this study provide valuable insights into TPACK knowledge of secondary mathematics teachers and offer implications for improving technology integration in mathematics education. The development of SMTTS addressed the need for a subject-oriented and culturally relevant measurement tool for assessing TPACK in the Chinese context. SMTTS offers a more precise assessment of mathematics teachers' TPACK knowledge by incorporating items specific to integrating digital technologies in mathematics instruction. Moreover, the study's results indicate that SMTTS demonstrates good reliability and validity, supported by statistical analyses such as EFA and CFA. The scale's face validity was ensured through a literature review, expert review, and pilot testing. Furthermore, SMTTS provides a comprehensive framework for measuring secondary mathematics teachers' TPACK, encompassing eight factors: CK, PK, TK, PCK, TCK, TPK, TPACK, and XK. Therefore, this study contributes to advancing research in TPACK knowledge among secondary mathematics teachers in China. The validated SMTTS provides a reliable measurement tool for future research studies and educational initiatives to promote the effective integration of digital technologies in mathematics education. By leveraging the findings, educators can strive to create engaging and impactful learning experiences that prepare students for the digital age.

Implications

There are five implications based on the findings of the study. First, the study contributes to the field by developing SMTTS, which is specifically designed for measuring TPACK knowledge domains of secondary mathematics teachers in the Chinese context. This scale addresses the need for a subject-specific and culturally relevant instrument that captures the unique challenges and practices of mathematics teaching in China. Second, the findings of this study contribute to a deeper understanding of mathematics teachers' TPACK competencies and readiness to integrate digital technologies in teaching and learning. This knowledge can inform teacher education programs, professional development initiatives, and curriculum designing efforts to enhance teachers' TPACK knowledge and improve technology integration in mathematics classrooms. Third, the study highlights the importance of considering the specific cultural and educational context when assessing TPACK. By incorporating the XK factor, SMTTS acknowledges the significance of context-specific knowledge and pedagogical practices that influence the successful integration of digital technologies in mathematics instruction. This understanding can guide educators and policymakers in developing contextually relevant strategies and support systems for effective technology integration. Fourth, this study opens avenues for future research in the field of TPACK and mathematics education. Further studies can explore the relationship between teachers' TPACK knowledge and students' learning outcomes, investigate effective pedagogical strategies for integrating digital technologies in mathematics instruction, and examine the impact of professional development programs on enhancing teachers' TPACK competencies. Fifth, while this study focuses explicitly on secondary mathematics teachers in China, the findings and implications can still provide valuable insights and serve as a reference for other countries. TPACK framework and the challenges of integrating digital technologies in mathematics education are relevant across different educational contexts. Although each country may have its unique cultural, educational, and technological landscape, there are often shared goals and challenges in enhancing technology integration in mathematics classrooms. Therefore, the findings from this study can inform and inspire researchers and educators in other countries to investigate and address similar issues within their contexts.

Limitations and Future Research

The study recruited participants from Chongqing Jiulongpo District in southwest China, which may limit the generalizability of the findings to other regions or contexts. Hence, it is recommended to conduct collaborative research projects that involve multiple countries or educational systems that can provide a broader perspective on TPACK in mathematics education. By including participants from different cultural and educational backgrounds, researchers can explore cross-cultural differences in TPACK knowledge and identify factors that influence technology integration in mathematics teaching. Such studies can enhance the generalizability of findings beyond a specific context. Additionally, the absence of items concerning AI in mathematics education could be considered a limitation of the study. As AI (e.g., ChatGPT) increasingly integrates into various aspects of education, it is vital to consider its role and impact on STEM teachers' knowledge and practices (Alneyadi & Wardat, 2023; Wardat et al., 2023). Therefore, adding items concerning AI in mathematics education to TPACK scale would strengthen the scale's relevance and applicability to the current educational landscape, particularly concerning emerging technologies. It would enable researchers to gain insights into teachers' perceptions and preparedness in harnessing AI for mathematics instruction, contributing to a more comprehensive understanding of TPACK in the context of AI integration.

Author contributions: ML: material preparation, data collection, data analysis, structural equation modelling, employed exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) to assess the scale's reliability and validity, drafted the initial manuscript; **AQN:** revised manuscript & validated statistical analysis; & **YL:** proofread final draft. All authors have agreed with the results and conclusions.

Funding: No funding source is reported for this study.

Acknowledgements: The authors would like to thank all participants who took part in this study & generously shared their insights. The authors would also like to thank Chongqing Teacher Education Training Center for their support in recruitment process & distribution of web-based questionnaire. Finally, the authors would like to thank the institutions & colleagues, whose support enabled carrying out this study. Their guidance and assistance were invaluable in completing this study.

Ethical statement: The authors stated that the study received the approval of the Monash University Human Research Ethics Committees, project number: 26687. This project includes data from compulsory education in mainland China, which refers to primary and secondary mathematics teachers. In this study, we used data from secondary mathematics teachers.

Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

REFERENCES

Acikgul, K., & Aslaner, R. (2020). Effects of GeoGebra supported micro teaching applications and technological pedagogical content knowledge (TPACK) game practices on TPACK levels of prospective teachers. *Education and Information Technologies, 25*(3), 2023-2047. https://doi.org/10.1007/s10639-019-10044-y

Alabdulaziz, M. S. (2021). COVID-19 and the use of digital technology in mathematics education. *Education and Information Technologies, 26*, 7609-7633. https://doi.org/10.1007/s10639-021-10602-3

Alneyadi, S., & Wardat, Y. (2023). ChatGPT: Revolutionizing student achievement in the electronic magnetism unit for eleventh-grade students in Emirates schools. *Contemporary Educational Technology, 15*(4), ep448. https://doi.org/10.30935/cedtech/13417

Angeli, C., Valanides, N., & Christodoulou, A. (2016). Theoretical considerations of technological pedagogical content knowledge. In M. C. Herring, M. J. Koehler, & P. Mishra (Eds.), *Handbook of technological pedagogical content knowledge (TPACK) for educators* (pp. 11-32). Routledge. https://doi.org/10.4324/9781315771328

Bingimlas, K. A. (2009). Barriers to the successful integration of ICT in teaching and learning environments: A review of the literature. *EURASIA Journal of Mathematics, Science and Technology Education, 5*(3), 235-245. https://doi.org/10.12973/ejmste/75275

Bryman, A. (2016). *Social research methods*. Oxford University Press.

Byrne, B. M. (2016). *Structural equation modeling with Amos basic concepts, applications, and programming*.

Routledge. https://doi.org/10.4324/9781315757421

Caniglia, J., & Meadows, M. (2018). Pre-service mathematics teachers' use of web resources. *International Journal for Technology in Mathematics Education, 25*(3), 17-34. https://www.proquest.com/docview/2131581135?pq-origsite=gscholar&fromopenview=true

Cao, Y., Zhang, S., Chan, M. C. E., & Kang, Y. (2021). Post-pandemic reflections: Lessons from Chinese mathematics teachers about online mathematics instruction. *Asia Pacific Education Review, 22*(2), 157-168. https://doi.org/10.1007/s12564-021-09694-w

Cetin, I., & Erdogan, A. (2018). Development, validity and reliability study of technological pedagogical content knowledge (TPACK) efficiency scale for mathematics teacher candidates. *International Journal of Contemporary Educational Research, 5*(1), 50-62. https://eric.ed.gov/?id=EJ1207506

Chai, C. S., Jong, M. S. Y., Yin, H. B., Chen, M. Y., & Zhou, W. Y. (2019). Validating and modelling teachers' technological pedagogical content knowledge for integrative science, technology, engineering and mathematics education. *Educational Technology & Society, 22*(3), 61-73. https://www.jstor.org/stable/26896710

Chai, C. S., Ng, E. M. W., Li, W., Hong, H. Y., & Koh, J. H. L. (2013). Validating and modelling technological pedagogical content knowledge framework among Asian preservice teachers. *Australasian Journal of Educational Technology, 29*(1), 41-53. https://doi.org/10.14742/ajet.174

Cohen, L., Manion, L., & Morrison, K. (2018). *Research methods in education*. Routledge. https://doi.org/10.4324/9781315456539

De Vita, M., Verschaffel, L., & Elen, J. (2018). The power of interactive whiteboards for secondary mathematics teaching: Two case studies. *Journal of Educational Technology Systems, 47*(1), 50-78. https://doi.org/10.1177/0047239518767112

DeVellis, R. F. (2017). *Scale development theory and applications*. SAGE.

Drijvers, P. (2015). Digital technology in mathematics education: Why it works (or doesn't). In S. J. Cho (Ed.), *Selected regular lectures from the 12th International Congress on Mathematical Education* (pp. 135-151). Springer. https://doi.org/10.1007/978-3-319-17187-6_8

Drijvers, P., Doorman, M., Boon, P., Reed, H., & Gravemeijer, K. (2010). The teacher and the tool: Instrumental orchestrations in the technology-rich mathematics classroom. *Educational Studies in Mathematics, 75*(2), 213-234. https://doi.org/10.1007/s10649-010-9254-5

Gao, X. (2021). The development of problem solving in Chinese mathematics curricula. In B. Xu, Y. Zhu, & X. Lu (Eds.), *Research in Mathematics Education* (pp. 87-108). Springer. https://doi.org/10.1007/978-3-030-68157-9

Giannakos, M. N., Doukakis, S., Pappas, I. O., Adamopoulos, N., & Giannopoulou, P. (2014). Investigating teachers' confidence on technological pedagogical and content knowledge: An initial validation of TPACK scales in K-12 computing education context. *Journal of Computers in Education, 2*(1), 43-59. https://doi.org/10.1007/s40692-014-0024-8

Gonzales, G. G., & Gonzales, R. R. (2021). Introducing IWB to preservice mathematics teachers: An evaluation using TPACK framework. *Cypriot Journal of Educational Sciences, 16*(2), 436-450. https://doi.org/10.18844/CJES.V16I2.5619

Graham, C. R. (2011). Theoretical considerations for understanding technological pedagogical content knowledge (TPACK). *Computers & Education, 57*(3), 1953-1960. https://doi.org/10.1016/j.compedu.2011.04.010

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). *Multivariate data analysis: A global perspective*. Pearson.

Hamad, S., Tairab, H., Wardat, Y., Rabbani, L., AlArabi, K., Yousif, M., Abu-Al-Aish, A., & Stoica, G. (2022). Understanding science teachers' implementations of integrated STEM: Teacher perceptions and practice. *Sustainability, 14*(6), 3594. https://doi.org/10.3390/su14063594

Harris, J. B., & Hofer, M. J. (2011). Technological pedagogical content knowledge (TPACK) in action: A descriptive study of secondary teachers' curriculum-based, technology-related instructional planning. *Journal of Research on Technology in Education, 43*(3), 211-229. https://doi.org/10.1080/15391523.2011.10782570

Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science, 43*(1), 115-135. https://doi.org/10.1007/s11747-014-0403-8

Ho, R. (2014). *Handbook of univariate and multivariate data analysis with IBM SPSS*. Taylor & Francis. https://doi.org/10.1201/b15605

Hoyles, C. (2018). Transforming the mathematical practices of learners and teachers through digital technology. *Research in Mathematics Education, 20*(3), 209-228. https://doi.org/10.1080/14794802.2018.1484799

Ifinedo, E., & Kankaanranta, M. (2021). Understanding the influence of context in technology integration from teacher educators' perspective. *Technology, Pedagogy and Education, 30*(2), 201-215. https://doi.org/10.1080/1475939x.2020.1867231

Khong, H., Celik, I., Le, T. T. T., Lai, V. T. T., Nguyen, A., & Bui, H. (2023). Examining teachers' behavioral intention for online teaching after COVID-19 pandemic: A large-scale survey. *Education and Information Technologies, 28*, 5999-6026. https://doi.org/10.1007/s10639-022-11417-6

Koehler, M. J., Mishra, P., & Cain, W. (2013). What is technological pedagogical content knowledge (TPACK)? *Journal of Education, 193*(3), 13-19. https://doi.org/10.1177/002205741319300303

Koh, J. H. L., Chai, C. S., & Lim, W. Y. (2016). Teacher professional development for TPACK-21CL. *Journal of Educational Computing Research, 55*(2), 172-196. https://doi.org/10.1177/0735633116656848

Koh, J. H. L., Chai, C. S., & Tsai, C. C. (2010). Examining the technological pedagogical content knowledge of Singapore pre-service teachers with a large-scale survey. *Journal of Computer Assisted Learning, 26*(6), 563-573. https://doi.org/10.1111/j.1365-2729.2010.00372.x

Li, M. (2023). Chinese mathematics teachers' TPACK and attitudes toward ICT integration in the post-pandemic era. *EURASIA Journal of Mathematics, Science and Technology Education, 19*(7), em2301. https://doi.org/10.29333/ejmste/13346

Mailizar, M., Hidayat, M., & Al-Manthari, A. (2021). Examining the impact of mathematics teachers' TPACK on their acceptance of online professional development. *Journal of Digital Learning in Teacher Education, 37*(3), 196-212. https://doi.org/10.1080/21532974.2021.1934613

Martinovic, D., & Karadag, Z. (2012). Dynamic and interactive mathematics learning environments: The case of teaching the limit concept. *Teaching Mathematics and its Applications, 31*(1), 41-48. https://doi.org/10.1093/teamat/hrr029

Mella-Norambuena, J., Cobo-Rendon, R., Lobos, K., Sáez-Delgado, F., & Maldonado-Trapp, A. (2021). Smartphone use among undergraduate STEM students during COVID-19: An opportunity for higher education? *Education Sciences, 11*(8), 417. https://doi.org/10.3390/educsci11080417

Ministry of Education the People's Republic of China. (2019). *The opinions on the implementation of the national primary and secondary school teachers' information technology application ability enhancement project 2.0*. http://www.moe.gov.cn/srcsite/A10/s7034/201904/t20190402_376493.html

Mishra, P. (2019). Considering contextual knowledge: TPACK diagram gets an upgrade. *Journal of Digital Learning in Teacher Education, 35*(2), 76-78. https://doi.org/10.1080/21532974.2019.1588611

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017-1054. https://www.tcrecord.org/content.asp?contentid=12516

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

Niess, M. L., Ronau, R. N., Shafer, K. G., Driskell, S. O., Harper S. R., Johnston, C., Browning, C., Ozgun-Koca, S. A., & Kersaint, G. (2009). Mathematics teacher TPACK standards and development model. *Contemporary Issues in Technology and Teacher Education, 9*(1), 4-24. https://citejournal.org/volume-9/issue-1-09/mathematics/mathematics-teacher-tpack-standards-and-development-model/

Noori, A. Q. (2021). The impact of COVID-19 pandemic on students' learning in higher education in Afghanistan. *Heliyon, 7*(10), e08113. https://doi.org/10.1016/j.heliyon.2021.e08113

Noori, A. Q., Orfan, S. N., Akramy, S. A., & Hashemi, A. (2022). The use of social media in EFL learning and teaching in higher education of Afghanistan. *Cogent Social Sciences, 8*(1), 2027613. https://doi.org/10.1080/23311886.2022.2027613

Patahuddin, S. M., Lowrie, T., & Dalgarno, B. (2016). Analyzing mathematics teachers' TPACK through observation of practice. *The Asia-Pacific Education Researcher, 25*(5-6), 863-872. https://doi.org/10.1007/s40299-016-0305-2

Porras-Hernández, L. H., & Salinas-Amescua, B. (2013). Strengthening TPACK: A broader notion of context and the use of teacher's narratives to reveal knowledge construction. *Journal of Educational Computing Research, 48*(2), 223-244. https://doi.org/10.2190/EC.48.2.f

Rakes, C. R., Stites, M. L., Ronau, R. N., Bush, S. B., Fisher, M. H., Safi, F., Desai, S., Schmidt, A., Andreasen, J. B., Saderholm, J., Amick, L., Mohr-Schroeder, M. J., & Viera, J. (2022). Teaching mathematics with technology: TPACK and effective teaching practices. *Education Sciences, 12*(2), 133. https://doi.org/10.3390/educsci12020133

Rezat, S. (2021). How automated feedback from a digital mathematics textbook affects primary students' conceptual development: Two case studies. *ZDM-Mathematics Education, 53*(6), 1433-1445. https://doi.org/10.1007/s11858-021-01263-0

Roni, S. M. (2021). *Data analysis with SPSS for survey-based research*. Springer. https://doi.org/10.1007/978-981-16-0193-4

Rosenberg, J. M., & Koehler, M. J. (2015). Context and technological pedagogical content knowledge (TPACK): A systematic review. *Journal of Research on Technology in Education, 47*(3), 186-210. https://doi.org/10.1080/15391523.2015.1052663

Sahin, I. (2011). Development of survey of technological pedagogical and content knowledge (TPACK). *The Turkish Online Journal of Educational Technology, 10*(1), 97-105. https://files.eric.ed.gov/fulltext/EJ926558.pdf

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

Scott, K. C. (2021). A review of faculty self-assessment TPACK instruments (January 2006-March 2020). *International Journal of Information and Communication Technology Education, 17*(2), 118-137. https://doi.org/10.4018/ijicte.2021040108

Scott, K. C., & Nimon, K. (2020). Construct validity of data from a TPACK self-assessment instrument in 2-year public college faculty in the United States. *Journal of Research on Technology in Education, 53*(4), 427-445. https://doi.org/10.1080/15391523.2020.1790444

Shi, Y., Zhang, J., Yang, H., & Yang, H. H. (2020). Effects of interactive whiteboard-based instruction on students' cognitive learning outcomes: A meta-analysis. *Interactive Learning Environments, 29*(2), 283-300. https://doi.org/10.1080/10494820.2020.1769683

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14. https://doi.org/10.3102/0013189X015002004

Su, X., Huang, X., Zhou, C., & Chang, M. (2017). A technological pedagogical content knowledge (TPACK) scale for geography teachers in senior high school. *Education and Science, 42*(190), 325-341. https://doi.org/10.15390/eb.2017.6849

Sun, S., Wu, X., & Xu, T. (2023). A theoretical framework for a mathematical cognitive model for adaptive learning systems. *Behavioral Sciences, 13*(5), 406. https://doi.org/10.3390/bs13050406

Tanu Wijaya, T. (2020). How Chinese students learn mathematics during the coronavirus pandemic. *IJERI: International Journal of Educational Research and Innovation, 15*, 1-16. https://doi.org/10.46661/ijeri.4950

Valtonen, T., Sointu, E., Kukkonen, J., Kontkanen, S., Lambert, M. C., & Mäkitalo-Siegl, K. (2017). TPACK updated to measure pre-service teachers' twenty-first century skills. *Australasian Journal of Educational Technology, 33*(3), 15-31. https://doi.org/10.14742/ajet.3518

Voogt, J., Fisser, P., Pareja Roblin, N., Tondeur, J., & van Braak, J. (2013). Technological pedagogical content knowledge–A review of the literature. *Journal of Computer Assisted Learning, 29*(2), 109-121. https://doi.org/10.1111/j.1365-2729.2012.00487.x

Wang, L., Liu, Q., Du, X., & Liu, J. (2017). Chinese mathematics curriculum reform in the 21st century: A review. *EURASIA Journal of Mathematics, Science and Technology Education, 13*(8), 5311-5326. https://doi.org/10.12973/eurasia.2017.01005a

Wardat, Y., Tashtoush, M. A., AlAli, R., & Jarrah, A. M. (2023). ChatGPT: A revolutionary tool for teaching and learning mathematics. *EURASIA Journal of Mathematics, Science and Technology Education, 19*(7), em2286. https://doi.org/10.29333/ejmste/13272

Willermark, S. (2018). Technological pedagogical and content knowledge: A review of empirical studies published from 2011 to 2016. *Journal of Educational Computing Research, 56*(3), 315-343. https://doi.org/10.1177/0735633117713114

Xiong, X. B., Chai, C. S., Tsai, C. C., & Liang, J. C. (2020). Exploring the relationship between Chinese pre-service teachers' epistemic beliefs and their perceptions of technological pedagogical content knowledge (TPACK). *Educational Studies, 48*(6), 750-771. https://doi.org/10.1080/03055698.2020.1814698

Yao, X., & Zhao, J. (2022). Chinese mathematics teachers' use of digital technologies for instruction: A survey study. *EURASIA Journal of Mathematics, Science and Technology Education, 18*(8), em2135. https://doi.org/10.29333/ejmste/12209

Zambak, V. S., & Tyminski, A. M. (2019). Examining mathematical technological knowledge of pre-service middle grades teachers with Geometer's Sketchpad in a geometry course. *International Journal of Mathematical Education in Science and Technology, 51*(2), 183-207. https://doi.org/10.1080/0020739x.2019.1650302

Zhang, J., Fang, Y., & Ma, X. (2010). The latest progress report on ICT application in Chinese basic education. *British Journal of Educational Technology, 41*(4), 567-573. https://doi.org/10.1111/j.1467-8535.2010.01083.x

APPENDIX A

Secondary Mathematics Teachers' TPACK Scale (SMTTS)

第一部分：人口统计学信息 (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）
    - 我的性别不在列表中。我认为我是：_________(My gender identity is not listed. I identify as:_________)
    - 无答案 /无可奉告 (Prefer not to say）
2. 任教年级 (Teaching grade)
    - 七年级 (Grade seven)
    - 八年级 (Grade eight)
    - 九年级 (Grade nine)
3. 年龄 (Age)
    - 20-29
    - 30-39
    - 40-49
    - 50-59
    - 60+
4. 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)
5. 教育背景 (Educational backgrounds)
    - 大学专科/专科 (Junior college)
    - 大学本科 (Bachelor's degree)
    - 硕士研究生 (Master's degree)
    - 博士 (Doctoral degree)
    - 其它 (Other)
6. 您的最高学历与数学教育有关吗？ (Is this degree in mathematics education?)
    - 是 (Yes)
    - 否 (No)
7. 有海外留学经历吗？ (Overseas study experience)
    - 是 (Yes)
    - 否 (No)

第二部分 TPACK (Part two: TPACK)

信息技术知识 Technological knowledge (TK): 利用信息技术完成各种任务的能力。TK can be thought of as the ability to accomplish various tasks using digital technology.

8. 学习信息技术对我来说很容易 (例如：国家智慧教育公共服务平台，钉钉，希沃电子白板等)。 I can learn technology easily (e.g., Smart Education of China, Seewo Interactive Whiteboard, and DingTalk).
   - 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. 我能紧跟中学数学教育中信息技术发展的脚步。I keep up with important new technologies in secondary mathematics education.
   - 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. 我经常探索如何有效地使用信息技术（例如：使用希沃电子白板，探索钉钉的教育教学功能， 学习数学软件等）。I frequently play around with the technology (e.g., Seewo Interactive Whiteboard, DingTalk, and mathematics software).
    - 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)

学科知识 Content knowledge (CK): 数学学科知识和能力，它包含数学理论、概念、模型、框架等等。CK is teachers' knowledge of a subject matter to be taught or learned. It encompasses theories, concepts, models, frameworks, existing practices, and methods for developing CK.

11. 我能用数学方式去思考问题（例如：熟知数学在生活中的例子， 常在生活中主动使用数学知识）。I can use a mathematical way of thinking (e.g., familiar with the examples of mathematics in real world situations, often using mathematics knowledge in real world situation).
    - 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. 我对数学教学内容的了解程度有足够的信心（数与代数， 图形与几何，概率与统计，综合与实践）。I am confident to teach mathematics content (number and algebra, figure and geometry, probability and statistics, and comprehensive practice).
    - 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. 我熟知2022年版《义务教育数学课程标准》。I am familiar with the "mathematics curriculum standards for compulsory education (2022 version)".
- 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)

教学法知识 Pedagogical knowledge (PK)：教与学的过程或方法的知识，它包括课堂管理、学生评估、了解学生如何学习和设计教学计划的知识等。PK refers to the knowledge regarding the process or approaches in teaching and learning, and it encompasses knowledge in classroom management, student assessment, comprehending how students learn and designing instruction plans.

14. 我能调整我的教学方式以适应不同的学生。I can adapt my teaching style to different learners.
- 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. 我能够设计具有挑战性的任务来拓展学生的思维。I am able to stretch my students' thinking by creating challenging tasks for them.
- 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. 我能在课堂上使用各种各样的教学方法（小组合作，探究式学习，项目式学习，翻转课堂，讲授法等等）。I can use a wide range of teaching approaches in a classroom setting (small group instruction, inquiry-based learning, project-based learning, flipped classroom, and teacher-centered instruction).
- 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. 我知道如何组织课堂教学和维持课堂秩序。I know how to organize and maintain classroom management.
- 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)

学科教学知识 Pedagogical content knowledge (PCK)：运用不同的教学策略和方法来实施数学课堂教学的知识。PCK refers to the knowledge that helps teachers apply different teaching strategies and methods to deliver the curriculum.

18. **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。I can engage students in solving real world problems related to mathematics without using technology.
    - 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. **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。Without using technology, I can facilitate a meaningful discussion about the mathematics content students are learning.
    - 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. **我能在不使用信息技**术的情况下，**帮助学生解决数学学**习中常遇到的困难。Without using technology, I can address the common learning difficulties my students have for mathematics.
    - 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)

整合技术的学科内容知识 Technological content knowledge (TCK)：了解不同的信息技术和数学学科知识是如何相互影响的知识。TCK is the knowledge that enables teachers to understand how different digital technologies and content are mutually influenced and limited in a specific discipline or domain.

21. **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**数学概念**。I can utilize technology tools (e.g., Seewo interactive whiteboard, PPT, and DingTalk et al.) to demonstrate mathematics knowledge and concepts.
    - 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. 我熟知可以用来研究数学教学内容的信息技术 （如：国家智慧教育公共服务平台，知网，数学软件等）。I know about the technologies that I can use for research on the content of teaching mathematics (e.g., Smart Education of China, CNKI, mathematics software et al.).
    - 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. 我能够使用数学软件进行数学学科的相关研究 （如：利用几何画板作图求长方体的体积， 使用Excel里的公式求平均数等）。I can use specialized software to perform inquiry about mathematics content. (e.g., using the Geometer's Sketchpad to draw cuboid and calculate its volume, and using Excel to calculate the mean).
    - 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)

整合技术的教学法知识 Technological pedagogical knowledge (TPK)：运用各种信息技术来优化教学策略和方法的知识。TPK is the knowledge that enables teachers to employ various digital technologies to optimize teaching strategies and methods.

24. 我能利用信息技术为数学课堂服务，提高学生的数学学习能力和学习效果。I can use technologies that enhance students' learning for mathematics lessons.
    - 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)
25. 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。My teacher education program has caused me to think more deeply about how technology could influence the teaching approaches I use in my classroom.
    - 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. 我不断深入地、批判性地思考如何在数学课堂上使用信息技术。I am thinking critically about how to use technology in my classroom.
    - 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. 我能将我学习的信息技术应用到不同的数学教学活动中。I can adapt the use of the technologies that I am learning about to different mathematics teaching activities.

- 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. 我能够帮助学生利用信息技术与同学们一起完成数学课堂活动和练习（例如：鼓励学生利用希沃电子白板进行小组学习成果展示）。I can facilitate my students to collaborate using technology in mathematics class (e.g., encouraging students to use Seewo interactive whiteboard to share group work).

- 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)

29. 我能够帮助学生利用信息技术完成家庭作业（例如：指导学生利用钉钉观看微课并完成相应的练习）。I can facilitate my students to finish homework by using technology (e.g., helping students use DingTalk to watch learning videos and complete related tasks).

- 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)

整合技术的学科教学知识调查 Technological pedagogical content knowledge (TPACK)：通过数学学科知识、教学法知识、信息技术知识整合所形成的复杂知识形式。TPACK使教师能够有效地将信息技术整合到数学学科教育教学中。TPACK is a complicated form of knowledge formed via CK, PK, and TK interaction. TPACK enables teachers to effectively integrate digital technologies into their teaching in a specific content domain.

30. 我能按数学教学内容设计教学活动，帮助学生使用恰当的信息技术来表达不同的数学知识（例如：在教师的帮助下，学生能使用希沃白板自带数学画图工具作图并分享学习成果）。 I can structure activities to help students to construct different representation of the content knowledge using appropriate digital technology tools (for example, with the help of teachers, students can use the mathematics drawing tool that comes with the Seewo interactive whiteboard to create diagrams and share learning results).

- 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. **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。 I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn.
   - 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. **我能**设计探究活动，**引**导学生合理地利用信息技术来理解数学知识 （**例如**：**帮助学生通**过平板电脑里的数学软件，通过小组合作的方式学习长方体的表面积）。I can design inquiry activities to guide students to make sense of the mathematics content knowledge with appropriate technology tools (e.g., I can help students use an iPad to learn the surface area of a cuboid in a group discussion).
   - 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. **我能根据数学教学内容**设计电脑和网络辅助的自主学习活动（例如：录制教学微视频并设计课后作业**来**让学生自主学习）。I can design self-directed learning activities of the mathematics content knowledge with appropriate technology tools (e.g., recording video courses and designing assignments for students’ self-learning at home).
   - 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)
34. 线上课堂中，我能**制定需要深入**讨论的数学学习内容，**并激励学生利用信息技**术**在**线**合作**学习（例如：**利用**腾讯会议平台的白板功能，让学生进行小组合作制作思维导图并进行**在**线**成果分享**）。I can formulate in-depth discussion topics about the mathematics content and facilitate students’ online collaboration with appropriate tools (e.g., using the digital whiteboard function of the Tencent Meeting platform, students can work together in groups to make mind maps and share results).
   - 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. **我能**设置与数学主题相关的现实生活问题，并通过**信息技**术**呈**现出来，吸引**学生参与数学学**习。I can set authentic problems related to mathematics topics and present them through technology tools to engage my students.
   - 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)

教学环境知识 Contextual knowledge (XK)：基于学校、地区、省、市、国家的角度，影响信息技术在数学教学中使用的因素的知识。XK has been defined as the knowledge that enables teachers to be aware of the factors impacting digital technology use in teaching and learning based on the perspective of schools, districts, states, or national policies.

36. 我了解班里学生的信息技术能力。I understand students' information technology skills in my classroom.
    - 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. 我了解学校有关提高数学教师信息技术能力的政策和措施。I understand the policies and measures to improve mathematics teachers' ICT capacity in my school.
    - 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. 我了解网络上有哪些可用于数学教育教学的应用程序和网络资源。I understand what software and network sources are available on the Internet for mathematics teaching and learning.
    - 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. 我了解提高数学教师信息技术能力相关的国家教育政策和措施。I know national education policies and measures for improving mathematics teachers' ICT capacity.
    - 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)