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

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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 (Hoeyes, 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...
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
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; Willerman, 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

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

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, TPK, 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.

**RESULTS**

The results revealed high reliability and validity of the newly developed TPACK instrument. The Cronbach’s alpha for the instrument was 0.92, indicating strong internal consistency. The factor analysis confirmed the construct validity of the instrument, with all items loading significantly on the respective factors. The instrument’s effectiveness in assessing teachers’ TPACK was further supported by its ability to discriminate between different levels of TPACK proficiency.

**DISCUSSION**

The findings highlight the importance of considering contextual factors in TPACK assessment. By incorporating a contextual construct, the new TPACK instrument provides a more accurate and comprehensive evaluation of teachers’ TPACK knowledge and practices. This instrument is a significant contribution to the field of teacher education, as it allows for more effective professional development and policy initiatives. Furthermore, the instrument’s cultural relevance to the Chinese educational context makes it a valuable tool for enhancing teaching and learning effectiveness in a technology-driven future.
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

<table>
<thead>
<tr>
<th></th>
<th>Pilot test</th>
<th>Formal questionnaire</th>
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<tr>
<td>Kaiser-Meyer-Olkin measure of sampling adequacy</td>
<td>928</td>
<td>916</td>
</tr>
<tr>
<td>Bartlett’s test of sphericity</td>
<td>Approximate Chi-square: 9,804.511 df 703 Significance &lt;.01</td>
<td>Approximate Chi-square: 7,804.929 df 496 Significance &lt;.01</td>
</tr>
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</table>

Table 4. Item removing explanation

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

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 (Ronli, 2021). The factor load minimum for each item was determined to be .40 (DeVellis, 2017). The authors conducted EFA for pilot 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.
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), \( \chi^2/df \), 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 5. Exploratory factor analysis pattern matrix principal component analysis (formal questionnaire) |
|-------------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Cronbach’s alpha                              | 1               | 2               | 3               | 4               | 5               | 6               | 7               | 8               |
| 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            |
Table 6. SMTTS fit values

<table>
<thead>
<tr>
<th>Fit indices</th>
<th>Good fit values</th>
<th>Acceptable fit values</th>
<th>SMTTS scale fit values</th>
</tr>
</thead>
<tbody>
<tr>
<td>(x^2/df)</td>
<td>.00&lt;(x^2/df)&lt;3</td>
<td>.00&lt;(x^2/df)&lt;5</td>
<td>1.295</td>
</tr>
<tr>
<td>RMSEA</td>
<td>.00&lt;RMSEA&lt;.05</td>
<td>.05&lt;RMSEA&lt;.10</td>
<td>.026</td>
</tr>
<tr>
<td>GFI</td>
<td>.95&lt;GFI&lt;1</td>
<td>.90&lt;GFI&lt;.95</td>
<td>.928</td>
</tr>
<tr>
<td>AGFI</td>
<td>.90&lt;AGFI&lt;1</td>
<td>.85&lt;AGFI&lt;.90</td>
<td>.913</td>
</tr>
<tr>
<td>NFI</td>
<td>.95&lt;NFI&lt;1</td>
<td>.90&lt;NFI&lt;.95</td>
<td>.929</td>
</tr>
<tr>
<td>CFI</td>
<td>.95&lt;CFI&lt;1</td>
<td>.90&lt;CFI&lt;.95</td>
<td>.983</td>
</tr>
<tr>
<td>TLI</td>
<td>.95&lt;TLI&lt;1</td>
<td>.90&lt;TLI&lt;.95</td>
<td>.980</td>
</tr>
</tbody>
</table>

Table 7. Convergent validity

\[
CR = \frac{\left(\sum_{i=1}^{k} \lambda_i\right)^2}{\left(\sum_{i=1}^{k} \lambda_i\right)^2 + \left(\sum_{i=1}^{k} 1 - \lambda_i^2\right)} \quad AVE = \frac{\sum_{i=1}^{k} \lambda_i^2}{k}
\]

<table>
<thead>
<tr>
<th></th>
<th>CR</th>
<th>AVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK</td>
<td>.820</td>
<td>.603</td>
</tr>
<tr>
<td>TPACK</td>
<td>.883</td>
<td>.602</td>
</tr>
<tr>
<td>XK</td>
<td>.876</td>
<td>.639</td>
</tr>
<tr>
<td>TPK</td>
<td>.901</td>
<td>.604</td>
</tr>
<tr>
<td>TCK</td>
<td>.847</td>
<td>.380</td>
</tr>
<tr>
<td>PCK</td>
<td>.828</td>
<td>.617</td>
</tr>
<tr>
<td>PK</td>
<td>.863</td>
<td>.612</td>
</tr>
<tr>
<td>TK</td>
<td>.853</td>
<td>.659</td>
</tr>
</tbody>
</table>

(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.

**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.
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 (Aciğkül & Aslaner, 2020; Zambon & 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 gain 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 Julongpo 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.

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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.

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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）。我可以轻松学习技术（例如：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。我跟上中学数学教育中信息技术发展的脚步。

   - 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)

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）。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）。

    - 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): 数学科知识和能力。它包含数学理论、概念、模型、框架等等。学科知识是教师对所教或所学内容的了解。它包括理论、概念、模型、框架以及已有的实践和方法。

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）。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）。

    - 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）。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）。

    - 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)
学科教学知识 Pedagogical content knowledge (PCK): 运用不同的教学策略和方法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)
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），

- 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)

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.

- 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)

- 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)

- 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)

**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)
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.

- **强烈认同 (Strongly agree)**
- **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、教学方法知识、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. I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn.
- Strongly disagree (Strongly disagree)
- Disagree (Disagree)
- Neither agree nor disagree (Neither agree nor disagree)
- Agree (Agree)
- Strongly agree (Strongly agree)

32. 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).
- Strongly disagree (Strongly disagree)
- Disagree (Disagree)
- Neither agree nor disagree (Neither agree nor disagree)
- Agree (Agree)
- Strongly agree (Strongly agree)

33. 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).
- Strongly disagree (Strongly disagree)
- Disagree (Disagree)
- Neither agree nor disagree (Neither agree nor disagree)
- Agree (Agree)
- Strongly agree (Strongly agree)

34. 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).
- Strongly disagree (Strongly disagree)
- Disagree (Disagree)
- Neither agree nor disagree (Neither agree nor disagree)
- Agree (Agree)
- Strongly agree (Strongly agree)

35. I can set authentic problems related to mathematics topics and present them through technology tools to engage my students.
- Strongly disagree (Strongly disagree)
- Disagree (Disagree)
- Neither agree nor disagree (Neither agree nor disagree)
- Agree (Agree)
- Strongly agree (Strongly agree)
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)