

Bridging the Gap: Barriers and Enablers of Technology Integration in Middle School Mathematics Teaching in China

Yi Fangyan^{1,2} & Khairul Azhar Jamaludin^{1,3,4}

¹Faculty of Education, Universiti Kebangsaan Malaysia, Bangi, Selangor, Malaysia, ²Changsha No.1 High School Yuelu Campus, Changsha, Hunan, China, ³University Research Group on ELITEE: Enhanced Learning for Inclusive Transformation Education Experience, ⁴University Research Group on Edexcellence: Development of Innovative Curriculum & Pedagogy

Email: khairuljamaludin@ukm.edu.my

Corresponding Author Email: P132263@siswa.ukm.edu.my

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Abstract

Recently, China's education system has steadily been undergoing digital transformation, where teachers, who presupposed all this, now understand the need for technology-based pedagogical content knowledge (TPACK). TPACK is nowadays acknowledged as the most critical variable for integrating technology into the teaching and learning process. Nevertheless, mathematics teachers in middle school still encounter difficulties in enhancing and modifying the educational models. The main reason lies in the culture of examination-oriented education, which is still prevalent in many areas of the country, and the strong existing inequalities in technological resources, in different areas of the country. Thus, the present study explored 100 middle school mathematics teachers' TPACK competencies in Changsha, China, and revealed determining factors of successful technology integration. The study adopted a cross-sectional survey to capture quantitative data and employed correlation and regression as tools to investigate the complex associations of resource access, training experience, environmental conditions, and individual characteristics. The results revealed a positive correlation between TPACK competencies and each of the factors, guided training, and institutional support, which were most strongly linked. Besides that, the teachers were still facing several problems, including lack of digital tools, insufficient professional development opportunities, and a curriculum focused on exams.

Keywords: TPACK (Technological Pedagogical Content Knowledge), Middle School Mathematics, Teacher Training, Technology Integration, Resource Availability, Professional Development, Educational Modernization

Introduction

As the times progress, the rapid digital transformation of education worldwide has reshaped teaching and learning practices, making the integration of technology an indispensable part of education reform (UNESCO, 2021). New technological education methods have spread to education systems around the world, and schools in China have also followed the pace of the

times and ushered in a new era of digital and information-based teaching methods. In China, promoting educational modernization has always been a national priority, and many policies emphasize the integration of technology into teaching practices (Zhang, 2019). Among these policies, the Ministry of Education of China advocates the use of technology to improve teaching efficiency and create learner-centered classrooms (Li & Lal, 2021). Although the intentions and ideas of these goals are very good, some educational resource issues and teachers' implementation of technology-based education are uneven, especially in secondary education. This study explores the teaching mastery level of middle school mathematics teachers in Changsha, focusing on their gaps in curriculum mastery and proposing important improvement strategies.

The concept of teaching mastery includes teachers' subject knowledge and their ability to effectively integrate teaching methods and technology to improve student learning outcomes. As noted by Ertmer & Ottenbreit-Leftwich (2010), the main uses where digital tools that can be accessed (i.e. interactive whiteboards, online platforms in the secondary mathematics environment) are intended to present complex concepts in a palatable and participatory manner. This study elaborates upon the barriers to accomplishing this goal. At present in Changsha, many teachers use technology mostly during administrative and basic content delivery purposes and lack technical experiences as far as interactive simulations and collaborative platforms are concerned (Tondeur et al., 2012). Additionally, access to technology- and professional-training in the education system both in urban and rural areas has only intensified the situation (Gao & Gao, 2019). Those schools which are urban ones have more of the advantages of resources and career development while rural schools have less. The same discrepancies for the deployment of digital resources between cities, and across the country have likewise been found and continued the issue of urban-rural digital divide (Zhang & Wang, 2021). That void is reflected in the quality, and equity of, teaching. To get past these obstacles, organizations must adopt systemic solutions for all learners. Reform programs through policy changes and teacher education will increase the widespread use of digital technology and make it more accessible for secondary mathematics education. Recent policy re-evaluations have also indicated that focused digital training and the equal opportunity to access technology are key to success in the adoption of them (Sun & Chen, 2020; OECD, 2021).

In the contemporary educational setting, the knowledge or ability of a teacher to implement cutting-edge frameworks including Technology Pedagogical Content Knowledge (TPACK) has emerged as an urgent problem that cannot be overlooked. In the past five years, it has been increasingly noted among scholars that TPACK is vital for effective teaching in technology-augmented classrooms (Schmid et al., 2021). TPACK theory was proposed by Mishra and Koehler in 2006. Its core purpose is to organically integrate technology, teaching methods and subject knowledge, build an integrated teaching strategy, and lay a solid theoretical foundation for modern educational practice. The current reality is that teachers do not have a sufficient understanding of the practical path of TPACK. If teachers want to master modern technology and implement it in the classroom, they cannot do without continuous and systematic professional training and special training. Some teachers have shortcomings in the internalization and application of the TPACK framework, which makes it difficult to fully release the potential of technology to empower teaching effectiveness and improve students' classroom participation. As Voogt and other scholars pointed out in 2013, this limitation has

become a constraint on the advancement of education quality. Especially when the COVID-19 pandemic swept the world, the traditional face-to-face teaching model came to an abrupt end, and the teaching scene suddenly turned online, exposing the shortcomings of many educators' insufficient technical capabilities. Problems such as disordered management of virtual classrooms and unfamiliar use of digital tools have frequently occurred, which has greatly reduced the creation of high-quality learning experiences. Hodges et al.'s 2020 study, as well as more recent analyses by Trust & Whalen (2020) and Carrillo & Flores (2020), provide evidence of these challenges.

In relation to China, this paper offers a case study of Changsha as a representative urban environment in order to portray a local perspective on the issues of technology integration in mathematics teaching. On the technological side, although Shanghai, the most developed city in China, has clearly been going ahead in the educational informatization field, a more thorough examination still exposes huge inequalities among middle school math teachers when it comes to the ability to use technology in teaching. First, such failures can be tackled in the area of supplying teachers with a broader level of digital competencies, online teaching tools, and developing teacher-targeted training resources. Previous research has raised similar concerns. For example, Wu (2019) pointed out the situation where teachers' technological skills and training options are limited.

China has always emphasized examination-oriented education. The exam-oriented teaching approach is not based on comprehensive learning of the topics with regard to conceptual understanding, but narrow terms of expression and exam thinking, making us capable of writing texts, not explaining concepts. Moreover, an examination-driven educational atmosphere usually creates an undesirable situation for teachers to try out new things, especially for technology-driven teaching methods. Those systemic and cultural conditions, as Zhao and Frank (2018) said, can be restrictive to the professional freedom of educators, erasing inventiveness right from the source. And thus, to overcome this high-quality teaching in mathematics of Changsha, and also to China as a country, this particular issue becomes critical to address. For this reason, the study intended to fill this gap in literature through a systematic examination of the technology integration competence of middle school math teachers. Through a survey study, TPACK teachers' mastery levels and main factors that enable and constrain teachers' efforts have been analyzed quantitatively, obviating the barriers that the profession encounters and highlighting the institutional support that is needed to be provided.

However, beyond the specific significance of this research for Changsha, it has significant benefits for other cities and states in China as well. In the end, addressing the real-world difficulties of teachers in employing classroom technology is crucial to the integration of technology into education in China. These obstacles should be identified and discussed, as smooth administration will orient the approach to the modernization of the Chinese educational system over time. In light of these wider objectives of enhancing both the quality and equity of Chinese education, this research, therefore, plans to specifically look into these problems and try to address these issues, so as to prepare students will be made ready to comfortably meet the challenges posed by the increasingly digitized world.

Besides the case of Changsha, this study is of importance not only to the second–tier cities but also the suburbs of China. The resolution of the problems hindering the Chinese middle school math teachers in the application of technology to the practice is critical to the achieving of a marvelous digitalization development in China. An awareness of the problems and a way to overcome them would essentially provide empirical supports in improving the compulsion education of China.

Specifically, this study aims to achieve the following core objectives:

- Assess the present TPACK skills of 100 middle school math teachers in Changsha, China, based on a recognized survey of the TPACK standard.
- The required factors for mastery of TPACK are resource availability, systematic training and organizational support, and environmental and personal factors according to TPACK’s analytical framework of the study.
- Explore the nature and strength of the relationships between these variables and the teachers’ TPACK skill level using Pearson correlation analysis, and estimate their relative contribution using multiple linear regression.
- Regarding the examination-focused education policy in China, the major barriers to technology integration, as well as their limitations, will be elaborated with the help of a qualitative analysis of respondents' responses to open-ended survey questions.
- Provide contextualized, customized recommendations to education policymakers, school administrators, teacher educators, and teacher training organizations to support the TPACK development of middle school mathematics teachers and the sustained, appropriate use of technology in their teaching practices.

In line with the national agenda to better the quality and equity of compulsory education in China, the present study aims to address the gaps left by the local TPACK literature, provide support to teachers for better technology integration in teaching, and assist students in developing the skills necessary to cope with the more digitalized society of the 21st century.

Literature Review

The literature review clearly presents the TPACK model, as well as the current situation of mathematics teaching in my country, but it goes further to explain the intricacy of technology education knowledge, which encompasses its theoretical and practical aspects, and reveals the practical difficulties it may encounter in practice, setting both a theoretical and practical basis for future research.

Theoretical Framework and TPACK Model

To provide curriculum development relying on pedagogical content knowledge integrated with the technological educational framework, there has been a progressive journey where the discrete applications have moved on to a big monolithic paradigm. The development of the TPACK model by Mishra and Koehler in 2006 is considered a major innovation, and it is a core principle of today's teacher training. In this model, the current educational paradigm is supplemented with Shulman's PCK model and includes the three key components: theory, pedagogy, and digital tools that facilitate the use of technology in education. TPACK—Technology, Pedagogy, and Content Knowledge—combines CK, PK, and TK not only as separate elements but also as interrelated parts, the intricate relations between which are emphasized. This approach gives teachers something they can actually use, an instrument, to allow them to assess and enhance their practice by reflection (Brianza & Petko, 2021).

The traditional pedagogical model tends to operate on the assumption that knowledge is somehow divided into the subject matter, the studying issues, and the difficulties with technology. When one's thinking aligns with a TPACK view, technology is not an independent item far off on the horizon, but a fundamental part of the teaching and learning processes that can actively help to overcome such obstacles. By this model, teachers can use those digital tools they feel most knowledgeable with to discipline where they have something to innovate on, figuring out lesson plans and strategies. This paper particularly narrows down TPACK to mathematics teaching and studies as the main focus. Online applications such as GeoGebra are also of a similar power to bring abstract mathematical concepts into more or less visual 3D models in an interactive environment when the phenomenon is interesting enough to involve the students' thinking in a more real way.

These technologies, through the effective conveyance of information, provide an environment that is conducive to learning and enables us to develop concepts and have participatory actions. The scientific evidence given by Voogt et al. (2013) supports the usefulness of such tools in both transforming the instructional quality and improving the student outcomes. Besides, the framework of TPACK clarifies that technology integration is a many-sided process that cannot be confined to a certain form of accomplishment. It goes beyond just the proficiency of the teacher; it involves the capability to reconstruct and make sense of divergent learning settings. The successful use of TPACK conditionally means TTA educators to harmoniously embed content, pedagogy, and technology in their learning practice while frequently evaluating and adapting methods to a distinctive context and educational learners' requirements. This point of view is being followed in the research works of Harris et al. (2009).

Although TPACK can be a major impetus for reforming the model of education, its practical terms of implementation is a complicated task. Educators need to grapple with the tensions that emerge from the dual nature of technology, which blends its novelty with pedagogical and scientific disciplines. This implies that the digital tool's efficient usage necessitates not only the technical proficiency but also the conceptual framework to recognize the intersection of knowledge in reality. Eventually, the mastery of TPACK application involves overcoming the challenges that are faced in order to achieve these outcomes.

Current Status of Mathematics Education in China

In China, educational systems that are traditionally balanced are characterized by a consistently formal and prescriptive approach. This is vividly evident from the reality that math education is one of the most rigidly focused subjects that are taught in China. Oftentimes, instructors are required to adhere to a predetermined, content-committed curriculum that pays homage to typical pedagogical frameworks. In most cases, this type of model or paradigm is concentrated on learning the basics as well as complex problem-solving, the latter of which seems to be the reason behind the high scores attained by the Chinese students in the international assessments like the Program for International Student Assessment (PISA). It has been established in several reports that people from China invariably take the top positions in worldwide exams (Li & Huang, 2013; Zhang, 2014). On the one hand, achieving these goals also presents challenges. Test dominance persists in China, consistently influencing the campus culture and encouraging a test-based society. On the contrary, through this method, students may be able to score high and thus contribute to the

happiness of teachers and parents. On the flip side, this model does not provide students with adequate chances to exercise their creativity and decision-making. Most of the time, memorizing factual information and doing drudge work are what characterize most of the classroom activity, which is seen as a limitation by more and more teachers with each passing day (Chen et al., 2020).

If teachers are stuck in an education system that is focused on outcomes—as is the case in many modern educational systems that stay with the lecture-based teaching style of previous generations—teachers tend to concentrate on short-term results that are passing marks rather than long-term learning. Within the Chinese education system, there are huge imbalances caused by such factors as geography, financial status, and social class. Consequently, urban schools enjoy better conditions in setting up high-tech and high-level organizations of technology, in addition to the teachers' skills in basic technologies, which could be improved through various ways, and the teachers could attain their goals as well as leading the majority of the high-tech education (Gao & Gao, 2019). Although these are affected by a lack of funding, aging infrastructure, and insufficient hands-on technical aid, it is still a challenging task. Such straightforward divides cause a rupture not only of unity in the educational ecosystem but also of the notion of learning technology integration. It should be a pressing priority for the use of technology in education to explore possibilities of bridging the crevice separating urban and rural schools.

Barriers to TPACK Mastery among Mathematics Teachers

The full embedding of the TPACK framework within China's mathematics education system is very challenging. Although mathematics teachers generally have rich content knowledge, most of them fall short in terms of technical skills and pedagogical skills to make the integration happen smoothly (Zhang & Zhu, 2016).

Professional development programs are critical points of intervention, but the existing methods are inadequate to ensure that the entire system is properly supported. The majority of teaching and training programs pay attention to the development of single knowledge areas, while the strengthening of the ability to use multiple skills simultaneously should attract more emphasis and recognition from the teachers and administrators. Although technology advances almost on a daily basis, teachers do not get continuous support from their educational institutions to be able to improve their skills (Hew & Brush, 2007; Ertmer & Ottenbreit-Leftwich, 2010).

These difficulties become even more serious in that they are combined with China's education system's test-based approach. Many teachers are inclined to continue to use the conventional method of teaching instead of learning new technologies, as they want more predictable academic outcomes and believe introducing new technologies will lead to disruption in the teaching process, thus making them more prone to errors compared to before.

Due to the safety-first attitude that is prevalent, this is particularly true for mathematics teaching, where, over the years, traditional approaches have produced strong performance indicators, meaning that anything outside the norm or traditional approach has a risk of failure (Zhao & Frank, 2018).

Another important obstacle to the development of modern education is the absence of resources, especially in rural areas, where there are problems with financial viability. The availability of technical devices, the challenges with infrastructure establishment, and the technical assistance deficiencies are the obstacles included in the idea of introducing modern education. The TPACK model, in some educators' minds, has been achieved to such a degree that they no longer consider it as realistic and, therefore, true.

It is as crucial as anything to recognize the fact that teachers equally experience stress and emotional strain, which arise as direct and indirect consequences of incorporating technology. A large group of teachers usually undergo a process of anxiety and fear when they have to operate the digital tools that keep on changing in real-time. The majority of middle-aged teachers are troubled by the idea if they will be able to properly drill the media of teaching that have developed and constantly doubt the viability of new ITs in education. Only by ensuring that the teaching quality is met in every aspect can they take it upon themselves to implement this measure with confidence. During this period of time, there are some practical technical problems that can be solved easily. But, in reality, the deeply-rooted psychological barriers towards technology education are much more challenging. Educational practice-behavior strategies are what they need when they are experiencing a crisis of self-confidence or have lost their self-efficacy.

Methodology

Research Design

To determine secondary school mathematics teachers' TPACK in Changsha, this research adopted a quantitative method with a cross-sectional survey design. The cross-sectional method provided a snapshot of teachers' TPACK status at a specific time, enabling the examination of relationships among key variables (Creswell, 2015).

Research Participants

The groups that participated were middle school mathematics teachers from Changsha, China. A total of 100 teachers participated in the survey. The sample consisted of teachers from different demographics (gender, age, years of teaching experience, and school location [urban versus rural]). These were included as significant variables in the disaggregated analysis, which also covered the mapping of differences between urban and rural teachers in TPACK mastery.

Research Instruments

The survey was also designed according to the TPACK framework by Mishra and Koehler (2006), and is indicative of the specific features of the Chinese education system. This questionnaire includes 4 main sections and responds to 4 dimensions of the research objectives:

1. Demographics: gender, age, number of years teaching experience, the place of school (urban vs. rural). These variables are an important element when performing subgroup analyses, which would be helpful to compare TPACK (Technology Pedagogical Content Knowledge) as an urban/rural factor among educators.
2. Evaluation of teacher proficiency across the central dimensions of TPACK, especially regarding technology knowledge (TK). This is mainly concerned with assessing the ability of

teachers to use digital tools for teaching. The second part relates to pedagogical knowledge (PK), which represents teachers' ability to form and execute effective instructional strategies. 3. Centers on content knowledge (CK), exploring teachers' knowledge about mathematical content and evaluating the extent of that knowledge. The integrated TPACK of the fourth section deals with teachers' capabilities to integrate technology, pedagogy, and content. Section three discusses the factors related to TPACK among secondary mathematics teachers. The questionnaires examined facilitators to teachers' technological competencies in three facets which are access to equipment, training and supporting environment, and personal and environmental factors. The first category was availability, which explored the availability of technology infrastructure and teaching materials at school. The second dimension, training and support, examined the success of teacher professional development opportunities and technology education programs. The third dimension (environmental and personal factors) investigated time constraints, personal technology confidence, and student acceptance of technology-based instruction, with optional open-ended questions included. 4. The last part consists of optional open-ended answers. Participants are encouraged to voice current problems and give their own unique angles of TPACK mastery. These responses make for qualitative data which can counterbalance and be enriched by other, more conventional measures.

The 2 and 3 were measured by a 5-point Likert scale from "strongly disagree" to "strongly agree" so that responses would be consistent and measured for analyses and processing. To achieve clarity and reliability, a pretest of the questionnaire was given to 10 mathematics teachers. The internal consistency of the results was high with Cronbach's alpha coefficients being above 0.8 in all constructs (Taber, 2018).

3.4 Data Collection Methods.

Data Collection Method

The final form of the questionnaire comprehensively covered all TPACK components, leaving no aspect unattended to, and the results obtained were both valid and reliable. The study was conducted under full disclosure, in which all participants were informed about their right to withdraw at any moment and the anonymity of their answers

Data Analysis Procedures

SPSS (Statistical Package for the Social Sciences) was used to conduct the analysis of the data collected. Analytical methods include descriptive statistical analysis, which encompasses demographic definition and level of TPACK mastery; correlation analysis, which examines the relationships between relevant factors and TPACK mastery; and regression analysis, which gives insights about main factors and plans of improvement concerning TPACK mastery levels. Open-ended questions were employed for checking the previous outcomes qualitatively.

Results

Pearson correlation analysis was conducted to examine the relationships between the independent variables and the dependent variable, mastery of TPACK core domains. The correlation coefficients in Table 2 showed that all independent variables demonstrated significant positive correlations with the dependent variable, with p-values less than 0.01, indicating high statistical significance.

Resources availability had a highly significant positive correlation with TPACK proficiency ($r = 0.891$, $p < 0.01$). Greater availability of resources is a clear indicator that people perform better at understanding TPACK concepts. Supportive resources to support educators to integrate technology and pedagogical content knowledge directly affect teaching outcomes. Second, TPACK mastery was significantly related to training and support ($r = 0.893$, $p < 0.01$). Structured training and effective support support the development of TPACK among teachers, enabling them to apply the TPACK framework in teaching practice. Such systems promote the acceptance of new technologies and their integration into curriculum practice. Lastly ($r = 0.845$, $p < 0.01$), there was a significant positive relationship between TPACK mastery and environmental and personal variables. This emphasizes the very significant role that teaching context and one's own attitudes have in teachers' utilization of TPACK. A strong teaching environment and continued usage are essential to promoting the complete integration of technology into education.

Access to resources, training and support, and environmental and personal factors were found to be significantly and positively related to TPACK mastery. Here, both external factors and internal factors of educators such as the resource and training and attitude and ability are emphasized, which promotes the development of TPACK in mathematics teaching to advance the innovation and effectiveness in education.

Table 1

Correlation Coefficients Between TPACK Mastery and Influencing Factors (n=100)

Variable	Mastery level of TPACK core areas (r, p)
Resource availability	0.891($p < 0.001^{***}$)
Training and support	0.893($p < 0.001^{***}$)
Environmental and personal factors	0.845($p < 0.001^{***}$)

Linear regression analysis was conducted to investigate the relationship between three independent variables—resource availability, training and support, and environmental and personal factors—and the dependent variable, mastery of TPACK. The results, summarized in Table 2, demonstrate the statistical significance of the model and the individual predictors.

Firstly, the F-test indicated a significant p-value ($F = 234.313$, $p < 0.001$), rejecting the null hypothesis that the overall regression coefficients equal zero. This suggests that the model is statistically significant, confirming the presence of linear relationships between the independent variables and TPACK mastery. Secondly, the R^2 value of 0.88 and the adjusted R^2 value of 0.876 imply that the model explains 88% of the variance in TPACK mastery, indicating a strong model fit. Variance Inflation Factors (VIF) for all predictors were below 10 (resource availability: 4.237; training and support: 3.993; environmental and personal factors: 3.254), demonstrating that multicollinearity does not affect the model, and the predictors are independently significant. Regarding the impact of individual predictors, all independent variables exhibited significant t-test results ($p < 0.05$), affirming their influence on TPACK mastery. Non-standardized regression coefficients showed that training and support had the greatest impact ($B = 0.375$), followed by resource availability ($B = 0.339$) and environmental

and personal factors ($B = 0.225$). Standardized coefficients (Beta) also revealed that training and support (Beta = 0.396) had the most substantial effect.

The final regression equation derived from the model is:

$$y = 0.211 + 0.339 \times \text{resource availability} + 0.375 \times \text{training and support} + 0.225 \times \text{environmental and personal factors}$$

In conclusion, all three predictors significantly and positively contribute to TPACK mastery. Among them, training and support exert the most profound influence, emphasizing its critical role in educators' ability to integrate TPACK effectively. These findings offer practical guidance for enhancing TPACK mastery through targeted improvements in training programs, resource allocation, and supportive environments.

Table 2

Linear Regression Analysis for TPACK Mastery Predictors (n=100)

Linear regression analysis results n=100									
	Unstandardized Coefficients		Standardized coefficients	t	P	VIF	R ²	Adjusted R ²	F
	B	Standard Error	Beta						
Constants	0.211	0.134	-	1.577	0.118	-			
Resource availability	0.339	0.068	0.365	5.011	0.000***	4.237			
Training and support	0.375	0.067	0.396	5.608	0.000***	3.993	0.88	0.876	F=234.313 P=0.000***
Environmental and personal factors	0.225	0.06	0.237	3.718	0.000***	3.254			

Dependent variable: Mastery level of TPACK core areas
 Note: ***, **, * represent 1%, 5%, and 10% significance levels, respectively

In summary, the results of correlation and regression analyses consistently indicate that the type and extent of training and support received by teachers, the availability of available technology resources, and several other individual and contextual variables significantly predict the TPACK competence of middle school mathematics teachers in Changsha. Among these factors, training and support mechanisms demonstrated the strongest explanatory power, highlighting the critical impact of systematic, high-quality professional development services on teachers' technology integration abilities. Furthermore, the availability of resources (such as appropriate tools and infrastructure support) has also been shown to be an important foundation for improving teachers' TPACK application abilities. Factors such as teachers' confidence, teaching attitudes, and specific teaching environments, however, were more dependent on the moderating effects of individual differences and context-specific variables. In short, this study has further verified that teacher training, high-quality teaching resources, and other quality assurance measures are fundamental to the development of TPACK, providing a foundation for adopting more effective and flexible mathematics teaching approaches.

Discussion

Elaborates on the understanding of factors that contribute towards teachers' formation of TPACK competencies, which are of high relevance to teacher professional development and policies. More specifically, the factors of resource, training and support in environmental and personal terms (Dunlavy et al., 2021) were identified as decisive in facilitating the integration of technology with pedagogy and subject knowledge. While most results are based on the precedent of previous studies in teacher education and training, further investigation is needed due to the current debates in literature.

Professional development is the best factor in predicting a teacher's TPACK mastery, according to the present study ($\beta = 0.396$). This finding aligns with prior research, emphasizing that systematic training is critical for educators to effectively integrate technology into classroom practice. The study also found that resource availability ($\beta = 0.365$) and environmental-personal factors ($\beta = 0.237$) are important. This suggests that TPACK development is mostly get influenced by institutional conditions and individual characteristics. In addition to the study, the correlation between resource availability and TPACK competence was positive ($r = 0.891$, $p < 0.01$). Hence, the investigation revealed that teachers who enjoyed abundant and varied availability of digital tools and instructional materials demonstrated a high level of power in technology integration into their classroom practice. Consistent with earlier studies, the present research findings show that the teaching-learning process requires resources (Koehler et al., 2014). Besides confirming the effect, it is crucial to note that the total amount and quality of available resources determines the level of academic progress students make.

The lowest Beta value among the predictors cannot distort the contribution significance of environmental and individual factors in TPACK competence (Beta = 0.237, $p < 0.01$). Classroom environments characterized by the endorsement of teachers and proof of teaching abilities, as well as teachers' positive attitudes towards technology and their own self-efficacy, could also play a major role in developing TPACK skills. While the findings are generally consistent with prior studies, in which both personal and situational variables were considered as significant contributors to teachers' professional development (Teo, 2019), the following point should be acknowledged, which is the fact that such findings might not be applicable in all school settings.

Even though the model displays the excellent level of explanatory power ($R^2 = 0.88$), it has some drawbacks that cannot be ignored. Currently, TPACK mastery is measured with self-report tools. This technique does, however, provide some information of value. Gaballo (2023) highlighted the problem that it is subject to social desirability bias, meaning that respondents might answer according to social norms instead of their actual situations, making the accuracy of results open to question. Future research could move beyond self-reported data and shift towards performance-based evaluations in actual classroom practice or systematic observations of TPACK teaching activities. Such approaches would lead to a more reliable conception of TPACK application.

There are limits in this study. First, the sample size is small and context-specific. It cannot be applied to a wider range. As Chai et al. (2016) pointed out, the influence of resource availability, training, and institutional support for TPACK development may vary from

different culture, institutional, and individual contexts. Future research should rely on a more heterogeneous and context-specific teacher sample. Even though this study is limited, it shows that TPACK development relies deeply on three factors. These factors are: enough resources, professional training, and institutional support. The results suggest that curriculum design in teacher education should integrate technology and pedagogy. Instead of regarding them as two separated parts, the combination of the two would yield better results. In addition, educational system should help teachers' professional development by supporting the teachers for a long time. In the future, qualitative or mixed-method research could be employed to carry out this research.

Conclusion

This study found that teachers' TPACK development relies on a combination of factors. These factors include availability of the technologies and instructional resources, opportunities for professional training, on-going institutional support and individual– context factors. Among the four, systematic opportunities for professional development and on-going support appeared to be the most significant factor in TPACK development. Besides, with enough teaching materials and a supportive environment together are critical factors for teachers. Because, with enough support and resources, teachers can combine technology, pedagogy, and subject knowledge into their instructions successfully.

On a theoretical note, the findings reveal the synergic effect of external support and individual traits, and therefore the decisive role of the holistic and context-oriented nature of the TPACK framework. In this regard, the research takes into account the practical applications for policymakers, school administrators, and teacher trainers, which implicitly mean that the development opportunities should be not only of a basic technical nature but also provide explicitly described strategies and methods for the integration of ICT tools in different teaching-learning situations. The existence of a strong and positive correlation between resource availability and TPACK skills points to the critical need of providing equitable access of quality teaching tools, as well as resources. In the similar manner, the factor of environmental conditions and personal attitudes stresses that the teacher education programs should be designed to promote teachers' confidence, self-efficacy, and collaborative culture among the community members.

Though this study has drawn some insightful conclusions, its methodological limitations must be noted. The TPACK data were mainly obtained from the self-reported questionnaire surveys. Subsequently, teachers' actual capacity to integrate technology should be measured through different yet more comprehensive and unbiased methods of assessing, including classroom observations and analyzing teaching behavior in future studies. Furthermore, this study was conducted on a sample specific only to that area; therefore, subsequent studies involving diverse educational systems and cultural backgrounds are suggested to increase the levels of generalizability and look into different institutional and individual factors that may affect the teachers' TPACK development. In the end, the article reiterates that TPACK continues to ground pedagogy. TPACK teachers mostly capitalize from workshops and experiences, incorporating more resources about deeper understanding and suitable design for instruction into their teaching schedule and promoting a more classroom-community sensitive atmosphere. By doing this, this affects the way the teacher does teaching and increases the achievement of students, advance the development goals of education in China.

Theoretical and Contextual Contributions

Theoretically, this study provides the much-needed contribution by confirming the TPACK framework in the context of middle school mathematics teaching in China's high-stakes assessment environment, which remains largely underexplored in existing literature. Although research has consistently adapted, tested, and confirmed the TPACK framework in developed educational contexts, it is scant that any studies have quantitatively estimated the relative effect of various factors operating in a high-stakes assessment environment in mathematics teaching in China. Interestingly, our result indicates that providing structured training and support ($\beta=0.396$) is a more critical antecedent of the teachers' TPACK proficiency over and above allowing access to resources, which contradicts the general assumption that resource availability drives technological adoption among teachers. Our study thus contributes to the generalizability of the TPACK framework by demonstrating the dominant role played by institutional support structures in high-stakes assessments.

Therefore, this study is contextually situated, which would enable implementation of appropriate, evidence-based interventions in educational practice in China, specifically. The majority of TPACK research in China deals with either primary schools or university education, with rather scant coverage of middle school math teachers, who intrinsically work in the context of the high-stakes senior high school entrance exam. Our study is based on Changsha, a second-tier urban center, which makes our conclusions valid for most urban and peri-urban regions in China and partially fills the gap of research on the first-tier megacities and completely secluded rural areas. Furthermore, the quantitative data on the main barriers to technology integration informs directly the curriculum design of teacher training courses, the policies of equitable resource allocation, and the supportive school management systems in comparable exam-focused educational systems.

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