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Technology Learning Experiences and Technology Skills: Pathways to Technology Integration for Pre-service Mathematics Teachers

Huanhuan Xiao
Faculty of Education, University of Malaya, Kuala Lumpur, Malaysia & Baoding University, Hebei Province, China, *s*2173551@*siswa.um.edu.my*

Kwan Eu Leong
Corresponding author, Faculty of Education, University of Malaya, Kuala Lumpur, Malaysia, *rkleong@um.edu.my*

Mohd Razip Bajuri
Faculty of Education, University of Malaya, Kuala Lumpur, Malaysia, *razip.bajuri@um.edu.my*

Technology integration is a core component of pre-service teacher education. However, the interplay between technology learning experiences and technology skills in shaping pre-service mathematics teachers' integration of technology remains unexplored. This study aimed to examine both direct and mediated relationships among these variables. To achieve this, social cognitive theory (SCT) and the Synthesis of Qualitative Data (SQD) model were integrated to propose and validate a conceptual framework. The results indicated that both technology learning experiences and technology skills had significant positive effects on pre-service mathematics teachers' technology integration. While learning experiences had a strong direct influence, technology skills contributed both directly and indirectly, partially mediating the relationship. These findings support the proposed model and suggest that technology skills acted as a complementary rather than dominant pathway for translating external conditions into effective technology integration outcomes. The study concludes that teacher education programs should systematically integrate SQD-based strategies into curricula to strengthen technology learning experiences and technology skills, thereby fostering more effective technology integration among pre-service mathematics teachers.

Keywords: pre-service mathematics teachers, technology integration, technology learning experiences, technology skills, structural equation modelling (SEM)

INTRODUCTION

The widespread use of information technologies has transformed both communication and education (Ma & Ismail, 2025). Teachers play a key role in this transformation, and

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their ability to integrate technology into teaching is critical (Njiku et al., 2019). However, research shows that both in-service and pre-service teachers are not adequately prepared, which can limit the meaningful use of technology and the potential benefits of digital learning (Tondeur et al., 2025).

In mathematics education, technology offers opportunities to enhance teaching and learning (Hutkemri et al., 2024; Leong & Parrot, 2018). Tools such as mobile, graphing calculators and mathematics software help students visualise concepts (Leong & Parrot, 2018), develop problem-solving skills, engage more actively in learning (Hutkemri et al., 2024), and support learner-centred instructional practices (Hanafi et al., 2025). At the same time, these digital tools allow teachers to adopt more varied and enriched instructional approaches (Hermita et al., 2021). Despite this potential, many teachers, including pre-service mathematics teachers (PSMTs) lack sufficient training and experience, which constricts their effective use of technology in the classroom (Hanafi et al., 2025; Pozas & Letzel, 2023). Therefore, strengthening digital skills training during teacher education is vital, ensuring PSMTs possess the competencies required to meet the expectations of in-service teaching and the evolving demands of society (Gu & Ding, 2022). Consequently, research and practice have focused on enhancing PSMTs' integration of technology in teaching.

To improve current teacher training programmes, prior studies have highlighted a range of factors that influence effective technology integration, including access to technology, teachers' attitudes (Ogbu, 2025), technology skills, and learning experiences (Farjon et al., 2019). The present study focuses on the roles of technology learning experiences and technology skills in PSMTs' technology integration. Technology learning experiences, such as role models and authentic experiences, provide meaningful opportunities for pre-service teachers to connect theory with practice, preparing them for future technology integration (Howard et al., 2021). Although prior studies have examined how these experiences influence technology integration, many focused on short-term, specially designed courses, raising concerns about whether these benefits persist within broader teacher education programmes. In fact, PSMTs' technology integration develops across the entire teacher preparation process, yet little is known about how these experiences shape their competence, highlighting the need for further empirical study.

To sum up, this research examined the relationships among technology learning experiences, technology skills, and technology integration among PSMTs, particularly in local Chinese universities. Accordingly, this study addressesed the following research questions:

1.Do technology learning experiences significantly influence technology integration among pre-service mathematics teachers?

2.Do technology skills significantly influence technology integration among pre-service mathematics teachers?

3.Do technology skills mediate the relationship between technology learning experiences and technology integration?

LITERATURE REVIEW

Technology Integration

Technology integration has been a primary focus in educational technology research, although scholars still debate its precise definition (Consoli et al., 2023). It is defined as the process of incorporating digital tools and services into educational settings (Education Resources Information Center, 2022), as the purposeful use of technology to achieve specific learning outcomes (Davies & West, 2014), and as the convergence of technology, pedagogy, and content knowledge, across subject contexts (Mishra & Koehler, 2006). These perspectives, however, often overlook the distinction between pre-service and in-service teachers. In China, Yan et al. (2018) define pre-service teachers' technology integration as the ability to apply technology to both foster autonomous learning and prepare future teachers for classroom practice. Overall, definitions vary widely, from technology-centred to pedagogy-based and context-responsive, suggesting that specific teacher populations and educational contexts must be considered. This study adopts the definition provided by Yan et al. (2018) to frame the investigation of pre-service mathematics teachers' technology integration.

Effective technology integration is widely recognised as key to improving teaching and learning (Consoli et al., 2023). However, its success depends on both external (or first-order) factors, such as infrastructure and institutional support, and internal (or second-order) factors, such as teachers' attitudes, skills, and beliefs (Ertmer, 1999). Previous studies consistently highlight that positive attitudes, technology skills, and learning experiences are the foundation for the successful implementation of technology in education (Christensen & Trevisan, 2022; Seufert et al., 2021). Nevertheless, it remains unclear how these factors influence the ongoing technology integration of pre-service mathematics teachers, pointing to an important research gap.

Technology Skills

Technology skills refer to pre-service and in-service teachers' confidence and ability in using technology and are widely acknowledged as essential for effective technology integration (Knezek & Christensen, 2016). Drawing upon the Will-Skill-Tool (WST) model (Knezek & Christensen, 2016), skills are considered a key individual factor within Social Cognitive Theory (SCT) (Ajzen, 1991), linking external factors with personal behaviours.

Previous studies have consistently indicated that teachers' technology skills play a major role in supporting the effective integration of technology in teaching (Dogan et al., 2020; Farjon et al., 2019; Seufert et al., 2021). For example, Agyei and Voogt (2011), using the WST model with pre-service and in-service mathematics teachers in Ghana, found that technology skills were the strongest predictor of successful technology integration, alongside teachers' attitudes and accessibility. Similar findings were observed in the Philippines, where technology skills again emerged as the most influential factor among science and mathematics teachers (Seufert et al., 2021). However, not all findings were consistent. A recent study found that mathematics teachers' technology skills did not significantly influence their integration practices

(Sawyerr & Agyei, 2022), suggesting that the impact of these skills may vary across contexts. Further investigation is therefore needed to examine how technology skills influence technology integration in different educational settings. Based on prior research, it is hypothesised that:

H1: Technology skills positively and significantly influence pre-service mathematics teachers' technology integration.

Technology Learning Experiences

Technology learning experiences refer to the quantity and quality of pre-service teachers' first-hand opportunities to integrate technology into their teaching during teacher education and training (Farjon et al., 2019). These learning experiences encompass six key components that collectively support the integration of technology. They include: observing instructors' use of digital tools in classroom settings (role models); engaging in reflective discussions on successful technology applications (reflection); designing or redesigning curriculum materials (instructional design); collaborating with peers in technology use (collaboration); applying technology in authentic situations (authentic experience); and receiving ongoing feedback from instructors (feedback) (Tondeur et al., 2016). These components, based on Tondeur et al.'s (2016) SQD (Synthesis of Qualitative Data) model, capture the opportunities and resources provided to pre-service teachers during their teacher training programme. In this study, technology learning experiences are conceptualised as an external environmental factor.

Research suggests that the depth and breadth of technology learning experiences play an important role in shaping pre-service teachers' ability to integrate technology effectively (Farjon et al., 2019; Tondeur et al., 2012). Consistent with this view, Farjon et al. (2019) found that the six micro-level strategies of the SQD model significantly influence pre-service teachers' technology integration. Other studies confirmed this, with SQD-oriented teacher education programmes facilitating better technology integration among pre-service teachers (Baran et al., 2017; Hsu & Lin, 2020; Lachner et al., 2021) . For example, a study with 215 pre-service teachers in Turkey demonstrated that SQD-based strategies positively predicted technology integration (Baran et al., 2017). Similarly, Lachner et al. (2021), using a quasi-experimental design, found that an SQD-based curriculum led to moderate improvements in technology integration compared with standard courses. Thus, pre-service teachers' access to comprehensive technology learning experiences is essential for the effective integration of technology.

However, existing studies have focused on specially designed modules or training interventions. Particularly within broader teacher education programmes, far less is known about the extent to which SQD-based technology learning experiences influence pre-service teachers' integration of technology. Building on this evidence, the study hypothesises that:

H2: Technology learning experiences positively and significantly influence pre-service mathematics teachers' technology integration.

Prior research also suggests that learning experiences strongly influence pre-service teachers' technology skills (Mouza et al., 2014; Qin et al., 2022; Sarri, 2021), highlighting their role in shaping technological proficiency. For example, Farjon et al. (2019) found that students' self-reported technology skills improved after a six-month pre-service teacher education programme, suggesting that such training enhances skills development. Likewise, Sarri (2021) showed that role models and reflection significantly enhance pre-service teachers' technology skills. In addition, participating in technology courses, observing technology-rich lessons (Mouza et al., 2014), and engaging in authentic teaching practice during internships (Qin et al., 2022) all support teachers' technology skills development. Collectively, these findings highlight that learning experiences of technology use effectively foster pre-service teachers' technology skills. Therefore, it is hypothesised that:

H3: Technology learning experiences positively and significantly influence pre-service mathematics teachers' technology skills.

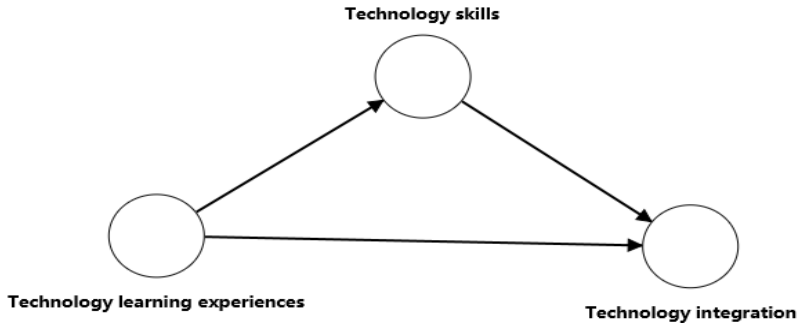
Finally, technology learning experiences and technology skills interact to influence technology integration (Farjon et al., 2019). Prior research indicates that technology skills not only affect teachers' technology integration but can also function as a mediating factor in this process (Dogan et al., 2020; Peng et al., 2023). Specifically, teachers with stronger technology skills are better equipped to integrate digital tools into their instructional practices (Dogan et al., 2020). These skills, in turn, help to explain how technology learning experiences are ultimately translated into effective technology integration. Based on this discussion of the relationships among technology learning experiences, technology skills, and technology integration, it is hypothesised that:

H4: Technology skills serve as a mediator between technology learning experiences and technology integration.

Hypothesis Model

Based on the research questions and hypotheses, the hypothesis model was specified to illustrate the relationships among technology learning experiences, technology skills, and technology integration among PSMTs, see Figure 1.

Figure 1
Hypothesis model



METHOD

Research Design

This study examined how technology learning experiences and technology skills collectively influence technology integration among pre-service mathematics teachers (PSMTs) in China. To capture both broad patterns and contextual nuances, the hypotheses were tested using partial least squares structural equation modelling (PLS-SEM). Given the proposed model's complexity and the study's predictive objectives, PLS-SEM was deemed the most suitable analytical approach, as it is particularly effective for examining complex relationships and developing theories (Hair & Alamer, 2022).

Participants and Procedures

Participants were final-year pre-service mathematics teachers who had completed their teacher education programmes. They were selected through cluster random sampling from local normal universities in Hebei, China, which specialise in teacher education and the professional preparation of future teachers. Data were collected online, with the survey made available via both a hyperlink and a QR code distributed through WeChat. After data screening, straight-line responses and outliers were removed from the dataset, resulting in a total of 581 final responses. This sample exceeded the minimum threshold for structural equation modelling analysis (Hair et al., 2019), ensuring both statistical robustness and representativeness of the target population.

Research Instrument

The survey included three scales: technology learning experiences (24 items across six dimensions: role models, reflection, instructional design, collaboration, authentic experiences, and feedback), technology skills (9 items), and technology integration (26 items covering resource preparation, process design, and practice reserve). In this study, technology skills and technology integration were measured using a five-point scale, while technology learning experiences used a six-point scale. The six-point scale for technology learning experiences was retained to maintain consistency with the original validated instrument. Because the analysis employed PLS-SEM, which standardizes indicators during estimation, the use of different Likert scales does not affect the analysis results. All scales were anchored from 'strongly disagree' to 'strongly agree'. The reliability and validity of these scales have been established in prior research. This study adhered to approved ethical standards, ensuring that all information provided remained strictly confidential.

Data Analysis

The questionnaire data were first entered into SPSS 28 and subsequently analysed using SmartPLS 4. SmartPLS is a widely used software for PLS-SEM, providing a robust option for model testing, with its advanced analytical capabilities, user-friendly interface, and flexibility in handling non-normal data and small-to-medium sample sizes (Hair et al., 2019). Using SmartPLS, the proposed model was validated, generating empirical evidence to better understand pre-service mathematics teachers' technology integration.

The analysis began with an assessment of the measurement model to verify construct reliability and validity, followed by testing the structural model to examine the hypothesised relationships. Since the model included a second-order reflective-reflective construct, a two-stage approach was adopted (Sarstedt et al., 2019).

FINDINGS

Measurement Model

The reliability and validity of the first-order measurement model were examined as outlined by Hair et al. (2019). Construct reliability was assessed through Cronbach's α and composite reliability (CR), both of which exceeded the recommended threshold of 0.7. As shown in Table 1, Cronbach's α values ranged from 0.801 to 0.875, indicating good internal consistency (Heale & Twycross, 2015), while CR values ranged from 0.873 to 0.905, further supporting the reliability of the constructs.

Convergent validity was evaluated using factor loadings and the average variance extracted (AVE). All factor loadings were greater than 0.6 (see Table 1). Although the recommended threshold is 0.7, removing items with loadings lower than that did not meaningfully improve CR or AVE for most constructs (Hair et al., 2022). However, for the Technology Skills construct, several items (including TS7, TS8, and TS9) were removed to ensure that the AVE exceeded 0.5. After these adjustments, all remaining loadings were greater than 0.6, and AVE values were above 0.5, indicating acceptable convergent validity (Fornell & Larcker, 1981).

Table 1
Construct reliability and validity for first-order constructs

Construct	Item	Loading	Cronbach's α	CR	AVE
Authentic Experiences (AE)	AE1	0.807	0.807	0.873	0.633
	AE2	0.780			
	AE3	0.844			
	AE4	0.749			
Collaboration (Co)	Co2	0.837	0.801	0.883	0.716
	Co3	0.844			
	Co4	0.857			
Feedback (Fe)	Fe1	0.853	0.856	0.903	0.698
	Fe2	0.861			
	Fe3	0.800			
	Fe4	0.828			
Instructional Design (ID)	ID1	0.732	0.822	0.883	0.654
	ID2	0.847			
	ID3	0.817			
	ID4	0.832			
Process Design (PD)	PD2	0.732	0.875	0.904	0.573
	PD3	0.720			
	PD4	0.781			
	PD5	0.768			
	PD7	0.745			
	PD8	0.788			
Practice Reserve (PR)	PR1	0.702	0.831	0.877	0.543
	PR2	0.713			
	PR3	0.701			
	PR4	0.772			
	PR5	0.759			
	PR6	0.770			
Role Models (RM)	RM1	0.833	0.860	0.905	0.705
	RM2	0.848			
	RM3	0.837			
	RM4	0.839			

Table 1 Continued

Construct	Item	Loading	Cronbach's α	CR	AVE
Resource Preparation (RP)	RP1	0.705	0.858	0.890	0.502
	RP2	0.697			
	RP3	0.720			
	RP4	0.709			
	RP5	0.749			
	RP6	0.724			
	RP7	0.651			
	RP8	0.709			
Reflection (Re)	Re1	0.781	0.834	0.889	0.668
	Re2	0.848			
	Re3	0.806			
	Re4	0.832			
Technology Skills (TS)	TS1	0.768	0.840	0.883	0.557
	TS2	0.783			
	TS3	0.726			
	TS4	0.786			
	TS5	0.742			
	TS6	0.667			

Discriminant validity of the measurement model was assessed through two widely accepted criteria: the Fornell-Larcker criterion (Fornell & Larcker, 1981) and the heterotrait-monotrait (HTMT) ratio of correlations (Henseler et al., 2014). As shown in Table 2, the square root of the AVE for each construct was greater than its correlations with other latent variables, suggesting adequate discriminant validity (Fornell & Larcker, 1981). In addition, a few items with high cross-loadings were removed to further refine the measurement model. Subsequently, all HTMT values remained below the recommended 0.9 threshold (Henseler et al., 2014) (see Table 3), thereby offering additional and robust evidence that discriminant validity among the latent constructs was satisfactorily established.

Table 2
Fornell and Larcker for first-order constructs

Construct	AE	Co	Fe	ID	PD	PR	RM	RP	Re	TS
AE	0.796									
Co	0.649	0.846								
Fe	0.740	0.611	0.836							
ID	0.687	0.673	0.701	0.808						
PD	0.539	0.562	0.555	0.606	0.757					
PR	0.629	0.601	0.631	0.651	0.748	0.737				
RM	0.531	0.650	0.489	0.600	0.557	0.551	0.839			
RP	0.507	0.531	0.537	0.578	0.756	0.709	0.544	0.708		
Re	0.570	0.596	0.619	0.685	0.558	0.599	0.638	0.575	0.817	
TS	0.401	0.406	0.358	0.408	0.491	0.456	0.399	0.499	0.402	0.746

Table 3
Heterotrait-Monotrait (HTMT) for first-order constructs

Construct	AE	Co	Fe	ID	PD	PR	RM	RP	Re	TS
AE										
Co	0.791									
Fe	0.894	0.734								
ID	0.843	0.824	0.837							
PD	0.633	0.669	0.639	0.713						
PR	0.762	0.735	0.747	0.787	0.876					
RM	0.624	0.783	0.566	0.707	0.642	0.649				
RP	0.599	0.634	0.620	0.682	0.867	0.835	0.627			
Re	0.691	0.729	0.732	0.829	0.653	0.719	0.754	0.676		
TS	0.482	0.497	0.420	0.487	0.570	0.542	0.469	0.584	0.478	

The second-order constructs (i.e., Technology Learning Experiences [TLE], Technology Skills [TS], and Technology Integration [TI]) were estimated using a two-stage approach, with the scores of the first-order reflective constructs serving as indicators for the second-order constructs (Sarstedt et al., 2019). They were then assessed for validity and reliability using the same procedures as the first-order model (Sarstedt et al., 2019). As shown in Table 4, Cronbach's α values exceeded 0.8 (0.894 for TI and 0.904 for TLE), while CR values were greater than 0.9, indicating acceptable internal consistency reliability. All factor loadings exceeded 0.7, while AVE values surpassed 0.5, indicating satisfactory convergent validity (Fornell & Larcker, 1981). As

shown in Table 5 and Table 6, both the Fornell-Larcker criterion and the HTMT ratio met the recommended standards, confirming adequate discriminant validity. This refined measurement model was subsequently used for the final structural model analysis (see Figure 2).

Table 4
Reliability and validity for the second-order constructs

Constructs	Items	Loading	Cronbach's α	CR	AVE
TI	PD	0.918	0.894	0.934	0.825
	PR	0.907			
	RP	0.900			
TLE	AE	0.856	0.904	0.929	0.723
	Co	0.830			
	Fe	0.861			
	ID	0.885			
	RM	0.856			
	Re	0.818			

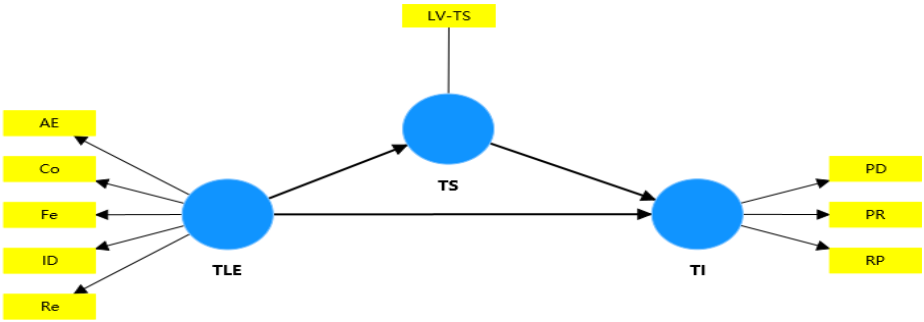
Table 5
Discriminant validity assessment: Fornell-Larcker

Constructs	Fornell–Larcker		
	TI	TLE	TS
TI	0.908		
TLE	0.750	0.850	
TS	0.530	0.465	1.000

Table 6
Discriminant validity assessment: HTMT

Constructs	HTMT		
	TI	TLE	TS
TI			
TLE	0.832		
TS	0.561	0.489	

Figure 2
The second-order measurement model



Structural Model

After evaluating the measurement model, the structural model was assessed. Collinearity was first examined using the variance inflation factor (VIF), with a recommended threshold of 3.3 (Hair et al., 2019). The obtained VIF values ranged from 1.000 to 2.964, suggesting that multicollinearity was not a concern.

Second, the structural model was assessed and validated using a percentile bootstrapping procedure with 5,000 resamples. The results of the path coefficient and mediation analyses are shown in Table 7. Technology Skills (TS) had a positive and significant direct effect on Technology Integration (TI) (β = 0.231, p < 0.001), supporting H1. Technology Learning Experiences (TLE) also had a positive and significant effect on TI (β = 0.642, p < 0.001), supporting H2. Similarly, TLE had a robust positive effect on TS (β = 0.465, p < 0.001), supporting H3. Meanwhile, TLE positively and significantly influenced TI through TS (β = 0.108, p < 0.001), indicating partial mediation and thus supporting H4. Overall, the results support all hypothesised direct and indirect paths, with TLE emerging as the strongest predictor of TI.

Table 7
Path coefficients and mediation results

Path	β	STDEV	T values	P values	Decision
H1: TS→TI	0.231	0.040	5.777	0.000	Supported
H2: TLE→TI	0.642	0.041	15.657	0.000	Supported
H3: TLE→TS	0.465	0.038	12.136	0.000	Supported
H4: TLE→TS→TI	0.108	0.022	4.860	0.000	Supported

Next, to evaluate the model's explanatory power, the coefficient of determination (R^2) and effect size (f^2) were analysed. R^2 values of 0.25, 0.50, and 0.75 were interpreted as weak, moderate, and substantial explanatory power, respectively (Hair et al., 2019). According to the results in Table 8, the proposed model explained 65.7% of the variance in TI (predicted by TLE and TS) and 28.3% of the variance in TS (predicted by TLE). These results suggest moderate-to-high explanatory power for TI and weak explanatory power for TS (R^2 = 0.283).

The effect sizes (f^2) were also examined to determine each construct's relative contribution, with benchmarks of 0.02 (small), 0.15 (medium), and 0.35 (large) (Hair et al., 2022). The findings showed that only TLE had a large effect on TI (f^2 = 0.389), while TS exerted only a small effect on TI (f^2 = 0.041). Similarly, TLE had a small effect on TS (f^2 = 0.061) (see Table 9).

Finally, the model's predictive potential was assessed using the Q^2 statistic from the blindfolding procedure. Q^2 values must be greater than 0 (Hair et al., 2022), and as shown in Table 10, all values met this criterion. Furthermore, the standardised root mean square residual (SRMR) value of 0.049 was below the 0.08 threshold (Hair et al., 2022), indicating an acceptable model fit.

Table 8
R^2 and Q^2

	R^2
TI	0.657
TS	0.283

Table 9
Effect sizes (f^2)

	f^2
TLE→TI	0.389
TS→TLE	0.061
TS→TI	0.041

Table 10
Predictive Relevance (Q^2)

	Q^2
TI	0.530
TS	0.274

DISCUSSION

This study examined the key factors influencing pre-service mathematics teachers' (PSMTs') technology integration, focusing on the relationships among technology learning experiences, technology skills and technology integration, with particular attention to the mediating role of technology skills in linking technology learning experiences to technology integration.

First, the findings demonstrated that technology learning experiences significantly predict PSMTs' ability to integrate technology. From the perspective of SCT, structured learning experiences may function as mastery and vicarious experiences that enhance pre-service teachers' capability to apply technology in instructional contexts. This suggests that meaningful learning opportunities, such as role models and authentic experiences, enable PSMTs to connect technological knowledge with effective classroom practice and build confidence in digital pedagogy. These results align with previous studies conducted in short-term, specially designed, SQD-based teacher education courses (Baran et al., 2017; Hsu & Lin, 2020; Lachner et al., 2021), which emphasise the importance of structured learning experiences in preparing teachers for technology use. Importantly, the current study extends these findings by showing that meaningful technology learning experiences continue to significantly enhance technology integration, even within general teacher education programmes not explicitly focused on it. Thus, instead of teaching technology in isolation, educators should embed digital pedagogy within mathematics courses. Using activities like micro-teaching or joint lesson planning lets students observe experts and get immediate feedback, helping them feel much more prepared before they start their actual teaching practice.

Second, the study found that technology skills significantly predict PSMTs' integration of technology. This finding is consistent with the WST model, which positions technology skills as a core enabling factor in technology integration. Thus, proficiency in digital tools provides the practical foundation for preparing digital resources, designing instruction, and delivering technology-enhanced lessons. This finding is consistent with prior research showing that teachers with higher levels of technology skills are more adept at integrating technology into their teaching (Hwang et al., 2023; Seufert et al., 2021). However, it is inconsistent with Sawyerr and Agyei's (2022) findings among in-service mathematics teachers, where technology skills did not significantly predict integration. The discrepancy may reflect differences in professional stage, as skills may play a more decisive role before teaching routines and contextual constraints become stabilised. This also suggests that, without adequate technology skills, experiences with technology may not translate into effective classroom use. Therefore, technology skills should be systematically strengthened in teacher education programmes as a prerequisite for effective integration.

Third, the result indicated that technology learning experiences play a key role in strengthening technology skills. This suggests that observing effective technology use, engaging in lesson design, and practising technology integration within teacher education settings facilitate the development of PSMTs' technology skills. This finding aligns with earlier research (Farjon et al., 2019; Sarri, 2021), reinforcing experiential engagement as a key pathway for developing technology skills. Therefore, teacher education programmes should focus on creating more technology learning experiences based on the SQD model. By engaging in observations, discussions, and feedback, PSMTs can better understand how digital tools work and correct their errors, which directly strengthens their technology skills.

Finally, the mediation analysis confirmed that technology skills partially mediate the relationship between technology learning experiences and integration. This implies that technology learning experiences must be internalised as specific skills before they can be effectively applied in the classroom. This result supports earlier research identifying technology skills as a mediator (Dogan et al., 2020; Nelson et al., 2019). However, the relatively small indirect effect observed in this study suggests that, in the current context, technology learning experiences still exert a stronger direct influence on integration. Technology skills appear to be a necessary but not sufficient condition for effective technology integration; they enable the translation of external experiences into classroom practice but do not fully account for their impact.

In contexts where access to digital infrastructure and learning opportunities are uneven, such as in local normal universities in China, technology learning experiences may play a more prominent role than skills alone. This pattern of partial mediation not only clarifies why previous studies have reported mixed findings but also sets the stage for further exploration of the broader theoretical and practical implications of the proposed model. It suggests that technology skills and technology learning experiences should not be viewed as isolated predictors of technology integration but as interrelated mechanisms. This refinement conceptualises technology skills as the bridge connecting external resources and pedagogical practice. In practically, teacher education should

focus on the quality of these learning experiences rather than just the quantity of resources. By turning their learning experience into functional skills through active tasks, such as using dynamic software to explore geometric proofs, pre-service mathematics teachers are better equipped to integrate technology into their future classrooms, regardless of how uneven the available resources might be.

CONCLUSION

This study examined and validated a model that integrates technology learning experiences and technology skills to explain pre-service mathematics teachers' (PSMTs') technology integration. Meaningful technology learning experiences and the skills developed through them jointly shape integrated practice. Importantly, technology skills function as the mechanism through which learning experiences translate into classroom integration, suggesting that learning opportunities alone are insufficient unless internalised as usable skills. By considering both direct and mediating pathways, the study provides deeper insights into the mechanisms that shape technology integration.

These findings offer both significant theoretical and practical contributions. Theoretically, by incorporating technology learning experiences based on the SQD model, the study highlights that technology integration is shaped not only by PSMTs' technology skills but also by the technology learning experiences embedded within their teacher education programmes. Teacher education programmes should systematically integrate SQD-based strategies (such as role model, authentic practice) into regular curricula to effectively translate technology accessibility and learning experiences into technology skills. By doing so, universities or institutions can better prepare pre-service teachers to implement technology in a meaningful and sustainable manner in their future classrooms.

Despite its valuable insights, this study has several limitations. First, data were only collected from pre-service mathematics teachers in local normal universities in China, which may limit the study's generalisability. Future studies should include other educational contexts to test the robustness of the model. Second, the study employed a quantitative cross-sectional approach, which limits causal inferences and may overlook changes in technology integration over time. Future research should employ longitudinal studies to track how technology learning experiences develop into skills and influence integration practices. Experimental interventions that manipulate key components of SQD-based learning experiences would allow researchers to test the causal inferences underlying the proposed model. In addition, combining survey data with classroom observations, interviews, could provide richer data on how external conditions are internalised as skills and translated into integration practices. Third, existing models have considered skills and learning experiences but not teacher attitudes (i.e., will), which are an important predictor of technology integration according to the WST framework. Future research could incorporate attitudes and examine the interactions among attitudes, skills, accessibility, and learning experiences to gain a more comprehensive understanding of technology integration among pre-service mathematics teachers.

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