

Article

From Needs Analysis to a Design Framework: Developing a Project-Based TPACK Mobile Learning Module for Pre-Service Teachers

Zhengjiao Fang^{1,2,*} , Hazrati Husnin¹  and Helmi Norman¹ 

¹ Faculty of Education, Universiti Kebangsaan Malaysia (UKM), Bangi 436000, Malaysia

² School of Resource and Environment, Aba Teachers College, Wenchuan 623002, China

* Correspondence: p129521@siswa.ukm.edu.my

Received: 31 March 2026; **Revised:** 15 April 2026; **Accepted:** 29 April 2026; **Published:** 20 October 2026

Abstract: The theory-practice gap in Technological Pedagogical Content Knowledge (TPACK) application remains a critical challenge for pre-service teacher education, particularly in rural and multi-ethnic contexts where instructional resources and context-specific examples are limited. As the first phase of designing, developing, and evaluating a project-based TPACK mobile learning module (TPACK-Pj), this study conducted a mixed-methods needs analysis to inform the development of a design framework. Quantitative data from 100 pre-service teachers and qualitative insights from 5 focus group participants were analyzed to identify current TPACK skill levels, instructional challenges, learning needs, and learning preferences. Results showed that pre-service teachers have moderate TPACK skills ($M = 3.15$), high perceived instructional challenges ($M = 3.87$), strong practice-driven learning needs ($M = 4.30$) and mobile learning preferences ($M = 4.36$). A significant positive correlation existed among challenges, needs, and preferences ($r = 0.546-0.840$, $p < 0.001$). No gender differences in TPACK skills were found, but males reported significantly higher challenges, needs, and mobile preferences (all $p < 0.05$). Based on these findings, this study proposed a design framework for the TPACK-Pj module, including five evidence-based design principles, a design-principle-to-technical-function mapping, and a scientifically structured modular architecture. The framework is designed for implementation on the Chaoxing platform, a widely used mobile learning system in China that offers both mobile app and web-based access, ensuring replicability and scalability. This study contributes a design-oriented, empirically grounded technical framework to the field of information and education technology, serving as the foundation for subsequent module development, usability testing, and effectiveness evaluation.

Keywords: TPACK; Pre-Service Teachers; Mobile Learning; Platform-Based Design; Teacher Education; Digital Technology Application

1. Introduction

With the advent of the Fourth Industrial Revolution (4IR), the field of education has been greatly impacted. Technology has changed the way people learn and teach [1–3]. For pre-service teachers, they not only need to acquire specific subject content knowledge and pedagogical knowledge but also must master the approaches of applying technology in teaching [4,5]. This is in line with the emergence of Education 4.0. Education experts use the term Education 4.0 to describe how to integrate technology into the learning process. Education 4.0 requires pre-service teachers to master technology to be integrated into the learning process [6]. The Standards for the Professional Competence of Teachers of Primary Education Students and the Standards for the Professional Competence of Teachers of Secondary Education Students issued by the Ministry of Education of the People's Republic

of China (MOE) highlight the importance of the skills to integrate technology in teaching process for pre-service teachers. Unfortunately, pre-service teachers have very little practical experience in selecting and integrating technology. Research has shown that pre-service teachers are not well-prepared to effectively integrate technology [7]. Therefore, strengthening teacher education and integrating it with digital literacy and pedagogical technology has become a priority in teacher education [6].

In the pre-service teacher training, the Technological Pedagogical Content Knowledge (TPACK) framework is a widely used model. It was expanded by Mishra and Koehler in 2006 based on Shulman's Pedagogical Content Knowledge (PCK) framework [8]. The TPACK framework consists of three basic components, which are content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK), as well as the four cross-components formed among them, namely technological pedagogical knowledge (TPK), pedagogical content knowledge (PCK), technological content knowledge (TCK), and technological pedagogical content knowledge (TPCK). The TPACK model indicates that a teacher's knowledge is complex and diverse [8]. Since the TPACK framework was proposed, it has been widely applied in the field of teacher education [9–11].

However, pre-service teachers encounter challenges in integrating technology due to factors such as lack of time, resources, and supports [12,13]. Research has shown that pre-service teachers have a good grasp of TPACK knowledge, but they encounter significant difficulties in converting this knowledge into practical operational skills [14–16], especially in rural and ethnic regions, such as southwest China [17,18]. In these regions, infrastructure and resources are relatively limited, so the curriculum is more focused on theoretical teaching rather than practical operations [19,20].

One possible solution to the difficulties of TPACK skills training for pre-service teachers is to integrate a training module where pre-service teachers can learn online via mobile devices and communicate with instructors and peers. Due to its convenience, flexibility and interactivity, mobile learning has become a bridge between formal and informal learning, more specifically, between formal classroom learning and informal learning [21]. Mobile learning breaks the limitations of time and space, enabling pre-service teachers to access teaching content, cases, micro-lesson resources and technological support anytime and anywhere [22]. This flexible learning can promote the continuous accumulation and update of technological knowledge (TK). Meanwhile, PjBL (Project-Based Learning) is a student-centered and problem-oriented learning approach that offers practical opportunities for pre-service teachers to integrate technology into their teaching. PjBL emphasizes the integration of knowledge into actual projects [23]. Research has shown that PjBL can promote the development of TPACK skills by enabling pre-service teachers to engage in authentic and hands-on teaching design tasks [23,24]. The mobile learning platform combined with PjBL can enable pre-service teachers to learn integrated TPACK knowledge flexibly and personally in practice and enhance TPACK skills. However, without a systematic and theoretically grounded instructional design, mobile learning initiatives risk becoming fragmented or technology-driven rather than pedagogy-driven [25].

To better design and develop the project-based TPACK mobile learning module (TPACK-Pj), the most important step is to analyze the needs of the learners. The needs analysis phase is included in the first phase of the Design and Development Research (DDR) proposed by Richey and Klein (2014) [26], followed by the design and development phase and the implementation and evaluation phase. The aim of this study is to identify the needs of the TPACK-Pj mobile learning module for pre-service teachers, thereby determining the design framework of TPACK-Pj module. Specifically, this study intends to answer the following three questions:

RQ1: What is the current TPACK skill level of pre-service teachers?

RQ2: What issues do pre-service teachers face when acquiring TPACK skills, and what are their learning needs and preferences?

RQ3: How to form the design framework of the TPACK-Pj module?

The TPACK-Pj module constructed in this study was developed based on the Chaoxing platform, a widely used learning platform in higher education in China that can be accessed through both web pages and mobile app. By developing based on the existing platform without customized software development, the cost for the promotion and use of this module has been reduced.

2. Literature Review

2.1. Technological Pedagogical Content Knowledge (TPACK) in Teacher Education

Mishra and Koehler (2006) developed Technological Pedagogical Content Knowledge (TPACK) framework (**Figure 1**) from Shulman's (1986) description of pedagogical content knowledge (PCK), which clarifies that content knowledge (CK) and pedagogical knowledge (PK) are the main focus of teachers' knowledge. Mishra and Koehler added technological knowledge as the third major knowledge to the PCK model, emphasizing teachers' understanding of the interaction between educational technology and PCK to use technology for effective teaching. Thus, there are three basic components in TPACK framework, which are CK, PK, and TK. The interaction between and among these three basic components are represented as technological content knowledge (TCK), technological pedagogical knowledge (TPK), pedagogical content knowledge (PCK), and technological pedagogical content knowledge (TPACK) [8], they are also crucial in this model.

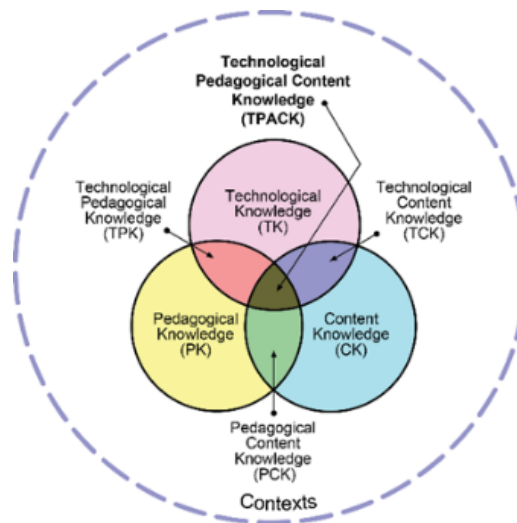


Figure 1. The TPACK framework and its components [8].

In previous studies, many researchers have explored TPACK in teacher education. Empirical studies indicate that developing TPACK is a complex and challenging process, particularly for pre-service teachers with little classroom experience [27]. Recent studies continue to show that although pre-service teachers often demonstrate basic digital skills, they find it difficult to successfully incorporate technology into instructional design and teaching practice [28]. During the process of developing TPACK, pre-service teachers need to constantly try, make mistakes and obtain feedback in real or simulated teaching scenarios [29]. Therefore, appropriate instructional approaches need to be adopted to enable pre-service teachers to acquire TPACK skills in real classroom teaching rather than just TPACK knowledge.

2.2. Project-Based Learning for TPACK Skills Development

Through engaging students in engaging experiences, project-based learning (PjBL) is a student-centred method of instruction that helps students understand and apply concepts. PjBL is a technique to boost student interest and assist in their comprehension of key concepts [23]. PjBL emphasizes students' self-directed learning and collaboration in real, meaningful projects, thereby developing students' skills that are needed in the 21st century. Since project-based learning was proposed, it has been widely concerned and studied by the educational community.

PjBL offers pre-service teachers an opportunity to practice and internalize TPACK in real tasks. For example, pre-service teachers engaged in project-based micro-lesson design must select digital tools that align with specific pedagogical strategies (e.g., collaborative learning) and content goals (e.g., science inquiry), this process directly cultivates the instructional TPACK skills required for classroom teaching.

Research has demonstrated that PjBL effectively promotes TPACK skills development when it is structurally designed for instructional practice [10]. Key instructional design features of effective PjBL for TPACK include clear

scaffolding for instructional design, opportunities for peer and teacher feedback on technology-integrated tasks, and reflective practice on instructional decisions [30]. Without these instructional supports, PjBL can be ineffective: pre-service teachers may focus on technological tool use at the expense of pedagogical quality, or experience cognitive overload when tasked with integrating multiple knowledge domains into instructional design [6]. This highlights the need for PjBL instructional design that is grounded in pre-service teachers' actual instructional challenges and needs.

2.3. Mobile Learning in Teacher Education

With the rapid development of mobile technology, mobile learning (or m-learning) has become an important trend in the field of education. It refers to the learning carried out across time and place through mobile devices such as smartphones and tablets, emphasizing flexible, personalized and sustainable learning experiences [31]. Due to its convenience, flexibility and interactivity, mobile learning provides significant support for the improvement of TPACK skills of pre-service teachers [32]. Mobile learning supports the iterative, context-dependent nature of instructional design: pre-service teachers can draft micro-lesson plans on mobile devices, access digital tool tutorials for classroom use, and receive timely feedback during the design process—all outside of the traditional lecture hall [33]. In contexts where pre-service teachers have limited access to formal computer labs, mobile learning becomes an even more critical instructional resource for TPACK skills development [34].

However, if mobile learning merely focuses on content delivery rather than skill training, then its effect on the development of TPACK skills will be greatly diminished [35].

Recent studies have emphasized the necessity of integrating mobile learning with instructionally focused pedagogical approaches (such as PjBL, task-based learning), which focus on real instructional design tasks [25]. For pre-service teachers, this means that the mobile learning module must be designed to support the entire instructional design process, from micro-lesson planning to the practice of digital tools to feedback and revision, rather than just delivering the TPACK theory or technical tutorials.

2.4. Needs Analysis for Instructional Design in Teacher Education

Needs analysis is a foundational step in instructional design [36]. In teacher education, needs analysis has been used to identify gaps between pre-service teachers' current competencies and desired professional outcomes, thereby informing the design of targeted learning experiences [36].

Recent design-oriented research further emphasizes the role of needs analysis in ensuring alignment among learner characteristics, instructional strategies, and technological features [37]. Mixed-method approach that combines quantitative surveys with qualitative interviews or focus group discussions are considered particularly effective, as they allow researchers to capture both broad trends and in-depth learner perspectives [38].

Despite extensive research on TPACK, relatively few studies have systematically employed needs analysis as a foundation for designing TPACK-oriented learning interventions, particularly in mobile and project-based contexts [39]. Moreover, empirical research focusing on pre-service teachers in China remains limited, especially regarding their current TPACK skills, perceived challenges, and learning needs prior to instructional design [40]. It is noteworthy, as technology integration in teacher education is shaped by context-specific factors such as curriculum structures, institutional conditions, and pedagogical expectations within the Chinese education system [41]. Although national policies increasingly emphasize the development of digitally competent teachers, there is still very little knowledge about how Chinese pre-service teachers engage with technology-integrated instructional design tasks, including micro-lesson development, in mobile and project-based learning environments [42]. Therefore, context-sensitive needs analysis research is needed to inform the localized design of project-based TPACK mobile learning module aligned with the practical realities of teacher education in China.

3. Methodology

3.1. Research Design

This study adopts a mixed-method research design that integrates both quantitative and qualitative approaches to investigate Chinese pre-service teachers' current TPACK skills and their needs of TPACK-Pj mobile learning module. The mixed-method approach is particularly suitable for studying educational phenomena that require both

statistical generalization of perception and in-depth exploration of complex experiential aspects [43]. Quantitative data were collected through a self-assessment questionnaire (N = 100) measuring pre-service teachers perceived TPACK skills, challenges, learning needs, and learning preferences. Although self-reported data is widely accepted in needs analysis studies, they are subject to potential response bias. This limitation is acknowledged and will be addressed in future studies by adding objective performance assessments. Qualitative data was obtained through a focus group discussion with 5 participants to further explore their experiences, challenges, and expectations, as well as learning environments and devices, given that the proposed module is intended to support a micro-lesson design course. It was designed to extend the questionnaire findings by exploring design-related aspects that could not be adequately captured through closed-ended items. The integration of quantitative and qualitative findings provided a comprehensive understanding of learners' needs and served as the empirical basis for module design.

3.2. Research Participants

In the needs analysis phase, the participants are the target users whose needs must be systematically identified. Therefore, purposive sampling technique was used in this study. A total of 100 pre-service teachers participated in this research. These pre-service teachers were senior students from the Aba Teachers College, who had taken the micro-lesson design course in the 2024/2025 academic year. They are majoring in education, covering areas such as Chinese, mathematics, English, physics, chemistry and biology education. Most of them have taken basic computer courses or multimedia courseware production courses and have also taken courses on subject instructional pedagogy or general education. The participants generally possess basic technological operation skills, such as creating PPT or making short videos. The demographic information of participants is shown in **Table 1**. Although the sample of 100 pre-service teachers from a single institution is adequate for descriptive and correlational analyses, we also recognize that this would limit its general applicability. The findings should be interpreted in conjunction with similar situations in rural teacher education institutions and this limitation will be addressed in future large-scale research.

Table 1. Participants' demographic information.

Demographic Info	Category	N	Percentage (%)
Gender	Male	43	43%
	Female	57	57%
	Below 19	14	14%
Age	20–21	69	69%
	22–23	17	17%
Total		100	100%

Subsequently, 5 pre-service teachers were purposively selected from the 100 pre-service teachers to participate in the focus group discussion. Before the discussion began, all participants clearly understood the research objectives, how their data would be used, and their commitment to protecting their privacy. After the participants confirmed these details, each participant signed a written consent form. Additionally, the academic and ethical committee of the university reviewed and approved the study to ensure it met ethical standards.

3.3. Research Instruments

3.3.1. Integrated Needs Analysis Questionnaire

To identify pre-service teachers' current TPACK skill levels, instructional challenges, learning needs, and learning preferences, the integrated needs analysis questionnaire with 43 items was used as the instrument. The questionnaire was based on the TPACK framework, mobile learning theory, and project-based learning principles. The questionnaire integrated a TPACK skills self-assessment component with additional needs analysis components. The TPACK skills self-assessment items were adapted from the validated TPACK assessment instrument developed by Schmidt et al. (2009) [44]. The needs analysis components were developed according to the themes determined by Utami et al. and Nousheen et al. in the literature on needs analysis [45,46].

The original TPACK items were rephrased to emphasize skill-oriented and practice-based abilities while maintaining the original factor structure. The needs analysis components were developed to identify pre-service teachers perceived challenges in acquiring TPACK skills, learning needs, and mobile learning preferences for mobile

learning module design. These items were adapted from literature [45,46]. A 5-point Likert scale, with 1 indicating “strongly disagree” and 5 indicating “strongly agree”, was used to measure each item. Before the questionnaire was distributed, it was reviewed by 2 experts in the field of quantitative research to determine the face validity and content validity. The structure of the questionnaire is shown in **Table 2**.

Table 2. Structure of the integrated needs analysis questionnaire.

Category	Number of Items	Example of Items	Total of Items
TK skills	1–7	I am able to use a variety of digital technologies to support teaching and learning activities.	7
CK skills	8–10	I am able to accurately apply subject content knowledge when planning and delivering instruction.	3
PK skills	11–16	I am able to assess students' learning performance using appropriate instructional methods.	6
PCK skills	17–19	I am able to select appropriate teaching strategies to help students understand subject-specific concepts.	3
TCK skills	20–23	I am able to use digital technologies to support students in understanding and solving subject-related problems.	4
TPK skills	24–28	I am able to use technologies to support and improve students' learning during classroom activities.	5
TPCK skills	29–33	I am able to design and implement lessons that effectively integrate content, pedagogy, and technology.	5
Challenges	34–37	I find it difficult to integrate technology, pedagogy, and content in lesson planning.	4
Learning needs	38–40	I need more opportunities to practice TPACK skills through project-based tasks.	3
Learning preferences	41–43	I prefer short, task-based learning activities delivered via mobile devices.	3
Overall			43

3.3.2. Focus Group Discussion Guide

To complement the questionnaire data and to obtain more in-depth needs for TPACK-Pj mobile learning module design, a semi-structured focus group discussion guide was adopted. The focus group discussion focused on four instruction-focused themes: (1) micro-lesson design challenges, (2) desired TPACK-Pj module content, (3) preferred mobile learning features, and (4) project-based learning expectations. The discussion lasted for 60 min and was recorded throughout.

3.4. Data Collection

The questionnaire was distributed online (100% response rate), with anonymous responses to ensure honesty. The focus group discussion was conducted face-to-face.

3.5. Data Analysis

Before the main study, 20 undergraduates from Aha Teachers College participated in the pilot study. The research showed that the questionnaire had good internal consistency, with Cronbach's α coefficients all above 0.7, which met the 0.70 criteria set by Brown [47]. **Table 3** presents the reliability of each subscale:

Table 3. The Cronbach's α of the questionnaire.

Category	Cronbach's α
TK skills	0.882
CK skills	0.900
PK skills	0.915
PCK skills	0.906
TCK skills	0.911
TPK skills	0.933
TPCK skills	0.946
Challenges	0.932
Learning needs	0.951
Learning preferences	0.895
Overall	0.952

Given the multi-dimensional nature of the TPACK framework, exploratory factor analysis (EFA) was conducted separately for each subscale to examine construct validity within the current sample. The KMO values for all seven subscales exceeded 0.60, and Bartlett's tests of sphericity were statistically significant ($p < 0.001$), indicating that

the data were suitable for factor analysis. For each subscale, a single-factor structure emerged with eigenvalues greater than 1, consistent with the original theoretical design. When all items were entered simultaneously, the correlation matrix did not meet factorability assumptions, likely due to the relatively small sample size ($N = 100$) in relation to the number of observed variables and the theoretical distinctiveness of the seven TPACK components. Therefore, subscale-level validation was considered methodologically appropriate.

The quantitative data were analyzed using SPSS 27.0. Descriptive statistical analysis (mean, standard deviation) was mainly employed to analyze the data on TPACK skill level, challenges, learning needs and preferences. The equal-interval classification method was used to divide the mean scores of the 5-point Likert scale into three categories: high (3.68–5.00), medium (2.34–3.67), and low (1.00–2.33). This classification was only used for descriptive interpretation.

Pearson correlation analysis was conducted to examine relationships among key instructional variables. Before correlation analysis, Shapiro-Wilk normality tests were conducted to verify data distribution. Although all variables reached statistical significance in the Shapiro-Wilk test ($p < 0.001$), the over-sensitivity of the test under medium sample size ($N = 100$) was considered. Combined with skewness ($-0.725 \leq \text{skewness} \leq 0.723$) and kurtosis ($-0.869 \leq \text{kurtosis} \leq 1.849$) indicators, all variables met the widely accepted loose normality criterion in social science research ($|\text{skewness}| < 2$, $|\text{kurtosis}| < 4$). Therefore, all variables were confirmed to be approximately normally distributed, which satisfied the precondition of Pearson correlation analysis. All statistical tests were two-tailed with a significance level of $\alpha = 0.05$, and missing data were handled via listwise deletion (missing rate $< 2\%$). Independent sample t -test was used to examine gender differences.

Qualitative data were analyzed with thematic analysis [48], following six steps: familiarization, initial coding, theme collation, theme review, theme definition, and report writing, focusing on instructional design needs that complement quantitative findings. Data were integrated using joint displays to facilitate the systematic integration of quantitative and qualitative findings [38].

4. Results

The analysis phase focuses on understanding pre-service teachers' views to guide the design of the TPACK-Pj module. This was achieved via self-reported questionnaires and focus group discussion. The entire process revealed levels of TPACK skills, instructional challenges, learning needs and mobile learning preferences, all of which require support in the pedagogical field.

4.1. Needs Analysis Finding

4.1.1. TPACK Skills and Instructional Challenges

Descriptive statistics (Table 4) revealed moderate overall TPACK skills ($M = 3.15$, $SD = 0.57$) among pre-service teachers, with mean scores across TPACK dimensions ranging from 3.02 (TK skills) to 3.22 (PK skills, TPK skills), indicating balanced but underdeveloped skills for technology-integrated instruction. In contrast, participants reported high perceived instructional challenges ($M = 3.87$, $SD = 0.96$) in micro-lesson design. This suggests that many pre-service teachers have faced significant difficulties when engaging in technology-integrated instructional tasks. Compared to the various dimensions of TPACK skills, the responses regarding the challenge dimension showed greater differences, which can be seen from the larger standard deviation. This indicates that pre-service teachers experienced differences in their experiences of challenges, with some reporting moderate difficulties and others considering effective technology integration as a significant barrier to quality micro-lesson design.

Table 4. Descriptive statistics of TPACK skills components and needs analysis ($N = 100$).

Category	N	Min	Max	Mean (M)	SD
TK skills	100	1.00	5.00	3.02	0.66
CK skills	100	1.00	5.00	3.03	0.74
PK skills	100	1.67	5.00	3.22	0.60
PCK skills	100	1.67	5.00	3.18	0.66
TCK skills	100	1.50	5.00	3.18	0.63
TPK skills	100	1.80	5.00	3.22	0.63
TPCK skills	100	1.20	5.00	3.21	0.63
Overall TPACK skills	100	1.45	5.00	3.15	0.57

Table 4. Cont.

Category	N	Min	Max	Mean (M)	SD
Challenges	100	1.00	5.00	3.87	0.96
Learning needs	100	2.00	5.00	4.30	0.68
Learning preferences	100	3.00	5.00	4.36	0.61

Note: All items were measured on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). M = mean; SD = standard deviation.

The results of the focus group discussion indicate that pre-service teachers lack the ability to integrate technology, pedagogy and content to design micro-lesson. Participants reported that while they possessed basic technological knowledge (TK) and pedagogical knowledge (PK), they struggled to make intentional instructional decisions that align these domains for micro-lesson design.

As one participant said:

"I tried using PowerPoint and CapCut for micro-lesson demonstrations, but I really don't know how to integrate technology into the course content in a way that supports teaching goals." (Participant 1)

Another key instructional challenge identified was limited experience with technology-integrated instructional design practice: participants reported that conventional instruction focused on theoretical knowledge of TPACK and digital tools, with few opportunities for hands-on micro-lesson design practice. Time constraints and limited access to contextually relevant instructional examples (e.g., micro-lessons for rural/multi-ethnic classrooms) were also cited as significant instructional challenges, as one participant 2 stated:

"We learn about digital tools in class, but we don't have time to practice using them for actual micro-lesson design, and there are no good examples of how to do this for the classrooms we will teach in." (Participant 2)

Similarly, participant 4 noted:

"I don't know when it's best to use technology to present instructional content." (Participant 4)

4.1.2. Learning Needs and Mobile Learning Preferences

Participants reported strong practice-driven instructional learning needs ($M = 4.30$, $SD = 0.68$) and very strong mobile learning preferences ($M = 4.36$, $SD = 0.61$) which is the highest mean score in the study (**Table 3**). Learning needs centered on three areas: hands-on project-based micro-lesson design practice, step-by-step instructional scaffolding, and contextually authentic examples. Mobile learning preferences focused on short task-based activities, flexible resource access, and mobile-enabled collaborative project work. The relatively high mean scores for these items indicate that pre-service teachers perceived practical engagement and instructional scaffolding as essential for effective TPACK skills development.

Qualitative findings elaborated two key learning needs: instructional scaffolding and timely formative feedback. The participants emphasized that project-based tasks were considered more effective than individual technical training, as they could simultaneously utilize technological, pedagogical, and content knowledge. Several participants emphasized the necessity of having support during the learning process. For instance, participant 3 said:

"I think step-by-step supports and real micro-lesson examples would help me learn faster" (Participant 3).

This finding aligns with the results of the questionnaire survey and indicates a strong need for step-by-step learning supported by examples and instructional guidance. Group discussion and hands-on projects were viewed as effective ways to enhance both technological and pedagogical understanding. For example, participant 2 explained:

"I hope to improve my skills through group discussion and project-based learning" (Participant 2).

As for mobile learning preferences, participants reported that mobile learning formats were particularly appealing due to their accessibility and flexibility. Moreover, participants consistently emphasized the importance of receiving feedback on lesson design and teaching tasks. As participant 3 said:

"I need feedback on my lesson design to know what to improve" (Participant 3).

Participants also emphasized the need for rural/multi-ethnic context relevance in all module content and tasks.

4.1.3. Correlation Analysis

Pearson correlation analysis was used to investigate the correlations between TPACK sub-skills, overall TPACK skills, instructional challenges, learning needs, and mobile learning preferences. Normality assumptions were confirmed prior to analysis. The findings are reported in **Table 5**:

Table 5. Correlation Matrix of Key Instructional Variables (N = 100).

Variable	1	2	3	4	5	6	7	8	9	10	11
1.TK skills	1										
2.CK skills	0.754**	1									
3.PK skills	0.672**	0.790**	1								
4.PCK skills	0.593**	0.683**	0.861**	1							
5.TCK skills	0.615**	0.621**	0.823**	0.877**	1						
6.TPK skills	0.571**	0.563**	0.802**	0.814**	0.935**	1					
7.TPCK skills	0.624**	0.654**	0.863**	0.830**	0.891**	0.930**	1				
8.Overall TPACK skills	0.810**	0.816**	0.933**	0.893**	0.917**	0.898**	0.929**	1			
9.Challenges	0.044	0.063	-0.141	-0.136	-0.173	-0.197*	-0.147	-0.105	1		
10.Learning needs	0.055	0.065	-0.066	-0.145	-0.167	-0.151	-0.094	-0.071	0.548**	1	
11.Learning preferences	0.028	0.088	-0.057	-0.116	-0.202*	-0.181	-0.1	-0.081	0.546**	0.840**	1

Note: N = 100. Pearson correlation coefficients are reported. ** $p < 0.05$; * $p < 0.01$ (two-tailed).

As shown in **Table 5**, results revealed that all TPACK sub-skills were strongly and positively intercorrelated (ranging from $r = 0.563$ to $r = 0.935$, $p < 0.01$), indicating that pre-service teachers' proficiency in one TPACK sub-skill was closely associated with their skills in others. Overall TPACK skills were also strongly and positively correlated with all TPACK sub-skills (ranging from $r = 0.810$ to $r = 0.933$, $p < 0.01$), suggesting that sub-skills collectively contribute to pre-service teachers' overall TPACK skills.

Additionally, the results revealed a significant positive correlation among perceived instructional challenges, learning needs, and mobile learning preferences (all $p < 0.01$). Most notably, needs and preferences were very strongly correlated ($r = 0.840$), indicating high alignment between what participants needed and how they preferred to learn. Challenges were positively correlated with both needs ($r = 0.548$) and preferences ($r = 0.546$), meaning pre-service teachers with greater challenges expressed stronger needs and mobile learning preferences.

4.1.4. Gender Difference

Gender differences in overall TPACK skills were not statistically significant, according to the independent samples t -test (**Table 6**), $t(98) = 0.64$, $p = 0.523$, meaning males and females possessed comparable TPACK skills. Similarly, no significant gender differences were observed in TPACK sub-skills (all $p > 0.05$).

Table 6. Gender differences in TPACK skills and instructional variables (N = 100).

Variable	Male (n = 43) M $\pm$ SD	Female (n = 57) M $\pm$ SD	t	df	p	Cohen's d
TK skills	3.16 $\pm$ 0.54	2.91 $\pm$ 0.72	1.95	98	0.054	0.39
CK skills	3.16 $\pm$ 0.69	2.94 $\pm$ 0.76	1.44	98	0.152	0.29
PK skills	3.20 $\pm$ 0.55	3.23 $\pm$ 0.65	-0.22	98	0.829	-0.04
PCK skills	3.17 $\pm$ 0.54	3.19 $\pm$ 0.74	-0.17	98	0.867	-0.03
TCK skills	3.17 $\pm$ 0.58	3.18 $\pm$ 0.68	-0.04	98	0.967	-0.01
TPK skills	3.22 $\pm$ 0.56	3.22 $\pm$ 0.69	0.02	98	0.986	0
TPCK skills	3.24 $\pm$ 0.48	3.19 $\pm$ 0.72	0.38	98	0.708	0.08
Overall TPACK skills	3.19 $\pm$ 0.49	3.12 $\pm$ 0.62	0.64	98	0.523	0.13
Challenges	4.34 $\pm$ 0.92	3.52 $\pm$ 0.84	4.67	98	<0.001	0.94
Learning needs	4.60 $\pm$ 0.71	4.07 $\pm$ 0.57	4.11	98	<0.001	0.83
Learning preferences	4.65 $\pm$ 0.57	4.14 $\pm$ 0.54	4.56	98	<0.001	0.92

Note: 1 = male, 2 = female. Two-tailed independent sample t -test were conducted. Cohen's d values represent effect sizes.

However, males reported significantly higher perceived instructional challenges ($t(98) = 4.67, p < 0.001$), learning needs ($t(98) = 4.11, p < 0.001$), and mobile learning preferences ($t(98) = 4.56, p < 0.001$) than females. Large effect sizes were observed for gender differences in instructional challenges ($d = 0.94$), learning needs ($d = 0.83$), and mobile learning preferences ($d = 0.92$), indicating substantial practical differences. In contrast, effect sizes for TPACK skills domains were trivial to small ($d = -0.04$ to 0.39).

4.2. From Needs Analysis to a Design Framework

Based on the needs analysis findings, this section presents a design framework for the TPACK-Pj mobile learning module. The framework is organized into four interconnected components: design principles, a design-principle-to-technical-function mapping, modular architecture, and implementation considerations for the Chaoxing platform.

4.2.1. Design Principles

Based on the above analysis results, five design principles are proposed. Each one directly addresses the specific results of the needs analysis. **Table 7** summarizes these principles and the empirical evidence that supports them.

Table 7. Evidence-based design principles for the TPACK-Pj module.

Principle	Description	Empirical Evidence
P1: Intentional, Fading Scaffolding	Provide structured support and gradually reduce the scaffolding support as the pre-service teachers' skills improve.	1. Moderate overall TPACK skills ($M = 3.15$) suggest foundational knowledge exists, but integration skills need support. 2. Qualitative data showed strong demand for "step-by-step supports and real micro-lesson examples."
P2: Authentic, Context-Embedded Project Tasks	The project tasks must be authentic and closely integrated with the specific context, enabling the participants to apply them in their future professional practice.	1. High instructional challenges ($M = 3.87$) are linked to a lack of context-specific examples. 2. Participants noted "no good examples of how to do this for the classrooms we will teach in."
P3: Formative Feedback	Integrate peer feedback and instructor feedback, delivered in ways that are timely, specific, and actionable.	1. Strong learning needs ($M = 4.30$) centered on feedback. 2. As one participant put it: "I need feedback on my lesson design to know what to improve."
P4: Mobile-first Design	Design for mobile devices as the primary access point, with short and focused activities.	1. Mobile learning preferences scored highest among all variables ($M = 4.36$). 2. Rural infrastructure constraints make mobile access more practical than computer labs.
P5: Gender-responsive Inclusivity	Address attitudinal and emotional differences between male and female learners without assuming skill gaps.	No gender differences in TPACK skills, but males reported significantly higher challenges, needs, and mobile preferences. This suggests instructional design should consider the different starting points in terms of confidence and motivation.

These principles are not meant to be applied in isolation. They work together: authentic project tasks (P2) provide the context for fading scaffolding (P1); mobile delivery (P4) enables timely feedback (P3); and gender-responsive strategies (P5) ensure that all learners can engage fully with the module.

4.2.2. Design-Principle-to-Technical-Function Mapping

Design principles become actionable only when translated into specific technical features [49]. **Table 8** maps each principle to a set of technical functions and shows how those functions can be implemented using the Chaoxing platform.

The reason for choosing the Chaoxing platform to implement the TPACK-Pj module was that it supported offline functionality, and all resources (such as text and videos) can be downloaded for offline use. It had a low-bandwidth optimization feature, which compressed the materials and video resolution to make the operation smoother. In addition, it also supported cross-device synchronization, including learning progress, peer-reviewed assignments and feedback. Automatic synchronization can be achieved through cloud storage. However, there were also some challenges in implementing this platform, such as students' unfamiliarity with functions like tasks and peer evaluations. To address these obstacles, the module conducted a "platform introduction" in the first week. This module followed a technical process of content upload, task allocation, interactive activities, feedback, and progress statistics. To enhance intelligence and engagement, this module integrated AI-based auxiliary teaching analysis to

achieve personalized scaffolding, as well as gamification elements such as progress rewards to improve motivation, which aligned with current educational technology trends [50,51].

Table 8. Design-principle-to-technical-function mapping with Chaoxing platform implementation.

Design Principle	Technical Function	Learning Activities Example	Chaoxing Platform Implementation
P1: Intentional, Fading Scaffolding	Phase-based task unlocking; template library; progress tracking and reminders	Micro-lesson design broken into three phases: (1) topic selection, (2) CK/PK/TK mapping, (3) full integration.	1.Task Points: Set video/chapter tasks as prerequisite learning objectives; students must complete Phase 1 tasks to unlock Phase 2. 2.Chapters: Organize content in sequential order; students can view their learning progress; teachers receive automatic notifications for incomplete tasks.
P2: Authentic, Context-Embedded Project Tasks	Context-specific case library; peer showcase; discussion forums	Participants analyze a micro-lesson video recorded in a rural school, then adapt it for their own subject area.	1.Materials: Upload prepared video cases of rural/multi-ethnic classroom instruction to the course materials section. 2. Discussion Forum: Students post case analysis and respond to peers; supports text, image, audio, and video uploads. 3. Group Tasks: Students submit final micro-lesson videos to group; supports peer viewing and commenting.
P3: Formative Feedback	Peer review rubrics; instructor comment interface; revision tracking; feedback notifications	After submitting a draft lesson plan, participants receive rubric-based feedback from at least two peers and one instructor.	1. Assignments with Peer Assessment: Enable peer review in assignment settings; set review deadline after submission deadline; students receive random peer submissions to evaluate using teacher-defined rubric; final score averages peer ratings 2. Instructor Grading: Instructors can modify peer scores and add written/audio comments. 3. Notifications: Students receive push notifications when feedback is available.
P4: Mobile-first Design	Micro-learning modules; responsive interface; just-in-time reminders	Complete a 7-min module on selecting appropriate digital tools for rural science teaching.	1. Xuexi Tong Mobile App: Native iOS/Android app of Chaoxing platform with complete course functions. 2.Messages: Push notifications for course updates, task reminders, and feedback notifications directly to mobile devices. 3. Tasks: Students can view and complete learning tasks on mobile; the progress of the tasks can be synchronized across different devices.
P5: Gender-responsive Inclusivity	Flexible grouping; customizable participation modes	All participants can freely choose their groups. One can receive encouragement from others.	1. Group Tasks: Teachers can set group formation methods, fixed groups, student self-selection, leader-formed groups, or random groups, allowing students to choose collaboration mode that suits their comfort level. 2. Quick Response and Random Selection: Optional interactive elements for students who prefer competition; can be used as optional rather than mandatory activities. 3. Discussion: Peer encouragement through comment threads.

4.2.3. Modular Architecture

The TPACK-Pj module was designed as a 16-week micro-lesson design course that systematically develops pre-service teachers' TPACK skills. Rather than treating TPACK as an unchanging knowledge system, the module structures learning experiences to progressively build competence across the seven TPACK dimensions. **Figure 2** provides an overview of this architecture, illustrating the step-by-step process from basic knowledge to comprehensive integration and application.

As shown in **Figure 2**, the module progresses from foundational knowledge (Phase 1, Weeks 1–3) to integration awareness (Phase 2, Weeks 4–6), then to scaffolded design practice (Phase 3, Weeks 7–12), followed by enactment through micro-teaching practice(Phase 4, Weeks 13–14), and concludes with consolidation and development (Phase 5, Weeks 15–16). It followed a progressive skill-building logic grounded in cognitive load theory and scaffolding theory. It progressed from foundational knowledge (TK, PK, CK) to integrated knowledge (PCK, TCK, TPK) and finally to comprehensive TPACK applications. This layered structure ensured gradual complexity and scientific alignment with pre-service teachers' developmental levels.

To illustrate how the TPACK-Pj module operates in practice, a case example is provided here. A pre-service teacher majoring in junior high school chemistry first entered the learning of Module 1, which included basic knowledge of TK, CK, and PK. Then, the learner moves on to Module 2, further understanding how to integrate these components into PCK, TCK, and TPK. In Module 3, the learner will conduct practical exercises. The learner will be required to complete a project-based micro-lesson design task, using virtual simulation software like No Book and generative AI to design and produce a 10-min micro-lesson video on “The Preparation of Chlorine Gas”. With the

scaffolding support of this module, case examples, as well as peer and teacher feedback, the learner revises and improves the lesson plan, forms a micro-lesson production script, and completes the micro-lesson video production. Finally, in Module 5, the learner will present the final work and reflect on it. This case demonstrates how this module gradually supports pre-service teachers in moving from basic knowledge to fully achieving the integration of TPACK.

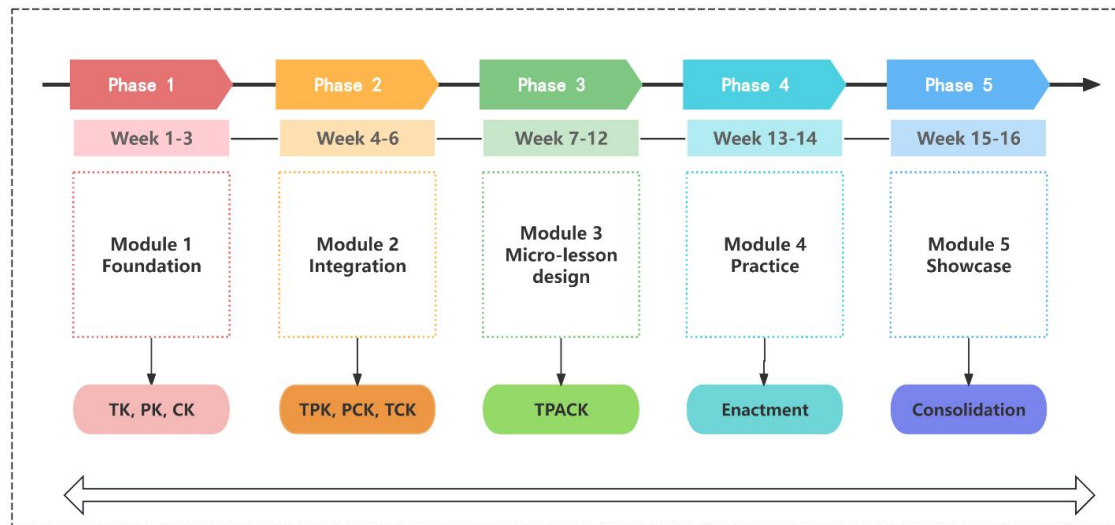


Figure 2. The modular architecture of the TPACK-Pj module.

5. Discussion

5.1. The Theory-Practice Gap (RQ1)

The study found that the TPACK skill level of pre-service teachers was at a medium level, which is consistent with the results of previous studies [52]. Participants possessed foundational TK, PK, and CK in isolation but lacked the ability to synthesize these domains, reflecting the TPACK theory-practice gap [28,53]. The prevalence of this gap in this study highlights the limitations of the common, theory-oriented TPACK instructional approach used in rural/multi-ethnic teacher education programs. Given that micro-lesson design is a fundamental teaching task that pre-service teachers in China undertake, this issue is particularly crucial. High perceived instructional challenges stemmed from limited context-specific examples, insufficient practice, and lack of scaffolding, unique to southwest China's rural/multi-ethnic context [52,54].

5.2. Learner Needs and Preferences (RQ2)

Participants reported strong practice-driven learning needs and very high mobile learning preferences, emphasizing hands-on micro-lesson practice, scaffolding, and timely feedback. These priorities align with constructivist [55] and show that pre-service teachers value pedagogy over tool access alone [35].

A strong positive correlation between needs and mobile learning preferences indicates pre-service teachers prefer mobile-based, practice-oriented support, which is highly suitable in rural contexts with limited computer access [34]. In addition, pre-service teachers also stated that they need formative feedback to determine their improvement directions [24,56], as well as contextual resources [54].

Regarding gender differences, this study did not find significant differences in the TPACK skill levels between male and female pre-service teachers, which is different from previous studies, such as Lu et al. and Yang et al. [57,58]. This might be due to differences in sample and measurement instruments. However, this is not an isolated case. As the latest Kosiol and Ufer's research shows, there is no significant gender difference in the overall dimension of TPACK [59]. This also illustrates the contextual nature of educational research. Since the samples were pre-service teachers from a university in a multi-ethnic area in southwestern China, most of whom came from rural

areas and had limited access to educational resources, the overall level showed no significant difference. However, male pre-service teachers scored higher than female pre-service teachers in terms of challenges, learning needs, and mobile learning preferences. This is consistent with the research of Gambari et al. [60]. This might be related to the relatively conservative attitude of female pre-service teachers when facing new technologies [61]. At the same time, this also indicates that when designing the TPACK-Pj module, attention should be paid to the emotional experiences of pre-service teachers of both genders [62].

5.3. The TPACK-Pj Design Framework (RQ3)

The design and development of the mobile learning module should be based on learners' needs and empirical evidence [63]. This study was based on the analysis of the needs of pre-service teachers and designed the TPACK-Pj mobile learning module based on the Chaoxing platform. This was presented in Section 4.2.

The mapping from findings to design principles to technical functions provides a level of specificity that is often missing in TPACK intervention studies. Rather than stopping at principles, the framework shows how to implement them using an existing platform that many teacher education institutions already use. This addresses a common criticism of educational technology research that it produces insights that are difficult to translate into practice.

Compared with the existing studies, this framework had its unique features. Firstly, most TPACK training programs focused on well-resourced settings, while this framework was specifically designed for rural and multi-ethnic environments, and its design principles were derived from the needs analysis in such environments. Secondly, the principles proposed in this study correspond to specific platform functions, making implementation easier, which is different from the general design principles proposed in existing studies. Finally, this module was placed in the micro-lesson design course and lasted for 16 weeks, respecting the actual structure of the teacher education project, making it more likely to be adopted than independent interventions.

In this study, five design principles of TPACK-Pj module were proposed, namely Intentional, Fading Scaffolding (P1), Authentic, Context-Embedded Project Tasks (P2), Formative Feedback (P3), Mobile-first Design (P4), and Gender-responsive Inclusivity (P5). Correspondingly, these five principles have been implemented on the Chaoxing platform, covering functions such as Task Points, Chapters, Materials, Discussion Forum, Group Tasks, Assignments with Peer Assessment, Instructor Grading, and Messages. The reason for choosing the existing platform Chaoxing for module design is that, on the one hand, there is no need to develop new software especially; on the other hand, this platform can be accessed through the web as well as the mobile app (Xuexi Tong app), which is very convenient. Moreover, this platform has been widely used in higher education in China, making it easy to promote the modules.

5.4. Limitations

Several limitations should be noted. Firstly, the research sample was limited to 100 pre-service teachers from a normal university in southwestern China. The sample was selected from a single institution and had a small size, which limited the generalizability of the research findings. Additionally, the data in this study mainly came from self-reported questionnaires, which were highly subjective and might not fully reflect the true situation. Therefore, future research is recommended to expand the sample size and use multiple instruments to collect data to mitigate these limitations. For example, including classroom observations, analyzing lesson plans, and analyzing micro-teaching videos, etc., to supplement the self-report data. Additionally, the design framework proposed in this study has not yet been implemented and evaluated. In the next stage, pilot implementation, pre- and post-tests, user acceptance evaluation, and usability evaluation will be conducted to evaluate the technical feasibility and implementation effectiveness.

6. Conclusions

This study aims to identify the needs of the TPACK-Pj mobile learning module for pre-service teachers, thereby determine the design framework of TPACK-Pj module. This study focused on pre-service teachers from rural, multi-ethnic southwest China. A mixed-method approach was employed to conduct the needs analysis, which is the first phase in designing, developing and evaluating the TPACK-Pj mobile learning module.

The findings revealed that participants had moderate TPACK skills, with balanced but underdeveloped integration skills across dimensions. They also reported high instructional challenges, particularly in synthesizing technol-

ogy, pedagogy, and content when designing micro-lessons. Qualitative data further reveal that pre-service teachers are aware of how to use technological tools, but they have difficulty integrating them with teaching intentions and content. Participants expressed strong practice-driven learning needs and very strong mobile learning preferences, desiring step-by-step guidance, authentic contextual examples, timely feedback, and hands-on project-based learning opportunities. A strong correlation was found between needs and preferences, indicating that what learners wanted to learn and how they wanted to learn were closely aligned. Regarding gender differences, no significant differences were found in TPACK skills, but significant differences were observed in perceived challenges, learning needs, and mobile preferences, suggesting that instructional design should attend to attitudinal rather than skill differences.

Based on the above findings, this study proposes a TPACK-Pj module design framework based on the Chaoxing platform. This framework consists of five design principles: (1) intentional, fading scaffolding; (2) authentic, context-embedded project tasks; (3) formative feedback; (4) mobile-first design; (5) gender-responsive inclusivity. Correspondingly, these five principles have been implemented on the Chaoxing platform, covering functions such as Task Points, Chapters, Materials, Discussion Forum, Group Tasks, Assignments with Peer Assessment, Instructor Grading, and Messages, which makes the framework actionable and replicable. This module is incorporated into a 16-week micro-lesson design course to enhance the TPACK skills of pre-service teachers.

This study has made contributions both in theory and practice. In terms of theory, this study can enrich the theory of mobile learning design. By conducting empirical needs analysis, it can obtain the issues of learners in acquiring TPACK skills, and also lays an empirical foundation for the subsequent development and evaluation of modules. In terms of practice, this study presents a context-based, mobile-supported TPACK skills development framework, providing supplementary resources for teacher education development and help build sustainable digital teaching capacity in under-resourced areas.

Author Contributions

Conceptualization, Z.F.; methodology, Z.F., H.H. and H.N.; software, Z.F.; validation, Z.F.; formal analysis, Z.F.; investigation, Z.F.; resources, Z.F., H.H. and H.N.; data curation, Z.F.; writing—original draft preparation, Z.F.; writing—review and editing, Z.F., H.H. and H.N.; visualization, Z.F.; supervision, H.H. and H.N.; project administration, H.H.; funding acquisition, Z.F. All authors have read and agreed to the published version of the manuscript.

Funding

This work was supported by the [Talent Special Project of Aba Teachers College, Research on the Obstacles to Technological Adaptation and the Path to Enhancing Digital Literacy of Teachers in Ethnic Areas of Sichuan Province under the Context of AI Empowerment], grant number [AS-RCZX2026-61].

Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of the Department of Research and Discipline Construction, Aba Teachers College (27th Mar, 2026).

Informed Consent Statement

Informed consent was obtained from all participants involved in the study.

Data Availability Statement

The data presented in this study are available on reasonable request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Acknowledgments

We are deeply grateful to everyone who has supported this work in different ways. We sincerely thank the students who participated in this study for their generous dedication to their time and experiences. We also express our gratitude to the teachers at the National University of Malaysia and the Aba Teachers College for their encour-

agement and valuable suggestions. Finally, we thank the reviewers for their careful feedback, which has greatly helped us to improve and strengthen this manuscript.

Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

AI Use Statement

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) solely for language refinement. No AI tools were used for data analysis, interpretation, or generation of scientific content. All outputs were critically reviewed and edited by the authors. The authors take full responsibility for the integrity and accuracy of the work.

References

1. Kumar, S. Education 4.0: Transforming Learning for the Fourth Industrial Revolution. *High. Educ. Future* **2025**, *12*, 144–162.
2. Maynard A.D. Navigating the Fourth Industrial Revolution. *J. Nature nanotechnology* **2015**, *12*, 1005–1006.
3. Lumadi, R.I. Reimagining Education Systems for Curriculum Justice in the Fourth and Fifth Industrial Revolutions. *Afr. Educ. Rev.* **2025**, *21*, 1–16.
4. Liesa-Orús, M.; Latorre-Coscolluela, C.; Vázquez-Toledo, S.; et al. The Technological Challenge Facing Higher Education Professors: Perceptions of ICT Tools for Developing 21st Century Skills. *Sustainability* **2020**, *12*, 5339.
5. Matar, S. The Development of Educational Technology and Artificial Intelligence and Their Impact on the Future of Education: Opportunities and Risks. *J. Posthumanism* **2025**, *5*, 1271–1292.
6. Tondeur, J.; Scherer, R.; Siddiq, F.; et al. Enhancing Pre-Service Teachers' Technological Pedagogical Content Knowledge (TPACK): A Mixed-Method Study. *Educ. Technol. Res. Dev.* **2020**, *68*, 319–343.
7. Aleksieva, L. Preparing Pre-Service Teachers for the Digital Transformation of Education: Exploring University Teacher Educators' Views and Practical Strategies. *Educ. Sci.* **2025**, *15*, 404.
8. Mishra, P.; Koehler, M.J. Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. *Teach. Coll. Rec.* **2006**, *108*, 1017–1054.
9. Koehler, M.J.; Mishra, P.; Kereluik, K.; et al. The Technological Pedagogical Content Knowledge Framework. In *Handbook of Research on Educational Communications and Technology*; Springer: New York, NY, USA, 2013; pp. 101–111.
10. Chai, C.S.; Koh, J.H.-L.; Tsai, C.-C. A Review of Technological Pedagogical Content Knowledge. *J. Educ. Technol. Soc.* **2013**, *16*, 31–51.
11. Lachner, A.; Fabian, A.; Franke, U.; et al. Fostering Pre-Service Teachers' Technological Pedagogical Content Knowledge (TPACK): A Quasi-Experimental Field Study. *Comput. Educ.* **2021**, *174*, 104304.
12. Silitonga, L.M.; Suciati, S.; Prastikawati, E.F.; et al. Bridging the Gap: Pre-Service Teachers' Realities of Technology Integration in the Digital Classroom. *ETERNAL (Engl. Teach. J.)* **2025**, *16*, 510–519.
13. Widiastutik, A.; Saraswati, G.P.D.; Wahyuni, S. Pre-Service Teachers' Experiences and Challenges in Creating Digital Learning Media Concerning TPACK Framework. *Lang. Circle* **2025**, *19*, 69–80.
14. Salleh, M.F.M.; Basri, A.S.M.; Ismail, M.H.; et al. Assessing Pre-Service Science Teachers' Technological Pedagogical Content Knowledge (TPACK) in the Hybrid Learning Environment. *J. Pendidik. IPA Indones.* **2025**, *14*.
15. Rakerda, H.; Lathif, M.; Amalia, R.; et al. From Knowledge to Practice: Investigating the TPACK Integration of Indonesian Pre-Service EFL Teachers. *Voices Engl. Lang. Educ. Soc.* **2025**, *9*, 71–85.
16. Aidong, W.; Noor, N.M. Systematic Review of Educational Technology Courses for Pre-Service Teachers: Trends and Challenges. *Int. J. Acad. Res. Prog. Educ. Dev.* **2025**, *14*, 106–120.
17. Gan, L. Research on Professional Development of Preschool Teachers in Ethnic Villages in Yunnan Province Under the Background of Education Informatization. *Int. J. Soc. Sci. Educ. Res.* **2024**, *7*, 112–119.
18. Li, M. Exploring the Digital Divide in Primary Education: A Comparative Study of Urban and Rural Mathematics Teachers' TPACK and Attitudes towards Technology Integration in Post-Pandemic China. *Educ. Inf. Technol.* **2025**, *30*, 1913–1945.

19. Jiong, Z. Analysis of the Differences and Causes of TPACK among Urban and Rural Teachers. *J. Teach. Educ.* **2019**, 6, 41–48. DOI: <https://doi.org/10.13718/j.cnki.jsjy.2019.04.006> (in Chinese).
20. Cheung, A.C.K.; Wong, K.L.; Wang, H.F.; et al. Effect of a Student Teaching Internship Program on the Self-Efficacy of Pre-Service Teachers in Rural China. *Int. J. Educ. Manag.* **2023**, 37, 373–392.
21. Criollo-C, S.; Guerrero-Arias, A.; Jaramillo-Alcázar, Á.; et al. Mobile Learning Technologies for Education: Benefits and Pending Issues. *Appl. Sci.* **2021**, 11, 4111.
22. Kukulska-Hulme, A. Mobile Usability in Educational Contexts: What Have We Learnt? *Int. Rev. Res. Open Distance Learn.* **2007**, 8.
23. Krajcik, J.; Blumenfeld, P. Project-Based Learning. In *The Cambridge Handbook of the Learning Sciences*; Cambridge University Press: New York, NY, USA, 2006; pp. 317–333.
24. Dewi, N.R.; Listiaji, P.; Aji, S. The Influence of Project Based Learning Model with TPACK Approach on the Teaching Skills of Pre-Service Science Teachers. In Proceedings of International Conference on Mathematics, Science, and Education, Semarang, Indonesia, 24 October 2023; pp. 53–58.
25. Qu, L.; Li, L. Implementation Strategy of Project-Based Learning in Mobile Learning Environments and Its Effects. *Int. J. Interact. Mob. Technol.* **2024**, 18, 4–18.
26. Richey, R.C.; Klein, J.D. *Design and Development Research: Methods, Strategies, and Issues*; Routledge: New York, NY, USA, 2014.
27. Bwalya, A.; Rutegwa, M.; Mapulanga, T. Developing Pre-Service Biology Teachers' Technological Pedagogical Content Knowledge through a TPACK-Based Course. *Eur. J. Educ. Res.* **2024**, 13, 263–278.
28. Cebi, A.; Özdemir, T.B.; Reisoğlu, İ.; et al. From Digital Competences to Technology Integration: Re-Formation of Pre-Service Teachers' Knowledge and Understanding. *Int. J. Educ. Res.* **2022**, 113, 101965.
29. Kelleci Alkan, Ö.; Aksoy, N.C.; Kulaksız, T.; et al. A Multi-Feedback System Integrated Simulation-Based Teacher Training to Scaffold Pre-Service Teachers' Teaching Skills: A Phenomenological Approach. *Educ. Inf. Technol.* **2024**, 29, 20691–20713.
30. Fazilla, S.; Bukit, N.; Sriadhi. Enhancing Prospective Teachers' Professional Competence: A Project-Based Learning Approach with the Technological Pedagogical Content Knowledge (TPACK) Model. *Kurd. Stud.* **2024**, 12, 1934–1945.
31. Sharples, M.; Taylor, J.; Vavoula, G. A Theory of Learning for the Mobile Age. In *The Sage Handbook of E-Learning Research*; Sage Publications: London, UK, 2006.
32. Srisawasdi, N.; Pondee, P.; Bunterm, T. Preparing Pre-Service Teachers to Integrate Mobile Technology into Science Laboratory Learning: An Evaluation of Technology-Integrated Pedagogy Module. *Int. J. Mob. Learn. Organ.* **2018**, 12, 1–17.
33. Criollo-C, S.; Abad-Vásquez, D.; Martic-Nieto, M.; et al. Towards a New Learning Experience through a Mobile Application with Augmented Reality in Engineering Education. *Appl. Sci.* **2021**, 11, 4921.
34. Tong, D.H.; Nguyen, T.-T.; Uyen, B.P.; et al. Using M-Learning in Teacher Education: A Systematic Review of Demographic Details, Research Methodologies, Pre-Service Teacher Outcomes, and Advantages and Challenges. *Contemp. Educ. Technol.* **2023**, 15, ep482.
35. Pedraja-Rejas, L.; Muñoz-Fritis, C.; Rodríguez-Ponce, E.; et al. Mobile Learning and Its Effect on Learning Outcomes and Critical Thinking: A Systematic Review. *Appl. Sci.* **2024**, 14, 9105.
36. Smith, P.L.; Ragan, T.J. *Instructional Design*, 3rd ed.; John Wiley & Sons: Hoboken, NJ, USA, 2004.
37. Antonenko, P.D.; Dawson, K.; Sahay, S. A Framework for Aligning Needs, Abilities and Affordances to Inform Design and Practice of Educational Technologies. *Br. J. Educ. Technol.* **2017**, 48, 916–927.
38. Creswell, J.W.; Clark, V.L.P. *Designing and Conducting Mixed Methods Research*; Sage Publications: Thousand Oaks, CA, USA, 2017.
39. Abd Manaf, C.J.; Desa, S.; Saad, M.I.M.; et al. Designing a TPACK-Based Mobile Learning Model for Biology Education Using the Nominal Group Techniques. *Environ.-Behav. Proc. J.* **2025**, 10, 29–35.
40. Yang, L.; Garcia-Holgado, A.; Martinez-Abad, F. Digital Competence of K-12 Pre-Service and In-Service Teachers in China: A Systematic Literature Review. *Asia Pac. Educ. Rev.* **2023**, 24, 679–693.
41. Xiao, J.; Wu, Y.; Jiang, X. Empowering Pre-Service Chinese Language Teachers with ICT Literacy: A TPACK-Based Model for Professional Growth. In Proceedings of the 2025 3rd International Conference on Educational Knowledge and Informatization, Chongqing, China, 11–13 July 2025; pp. 492–499.
42. Sun, X.; Hamdan, A.R.B. The Effect of Micro-Lesson Design on TPACK Level Development of Pre-Service English Teachers in China. *Int. J. Sci. Eng. Appl.* **2023**, 12, 230–233.
43. Creswell, J.W.; Creswell, J.D. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, 4th ed.; Sage Publications: Hoboken, NJ, USA, 2017.

44. Schmidt, D.A.; Baran, E.; Thompson, A.D.; et al. Technological Pedagogical Content Knowledge (TPACK): The Development and Validation of an Assessment Instrument for Preservice Teachers. *J. Res. Technol. Educ.* **2009**, *42*, 123–149.
45. Utami, P.; Pahlevi, F.; Santoso, D.; et al. Android-Based Applications on Teaching Skills Based on TPACK Analysis. *IOP Conf. Ser.: Mater. Sci. Eng.* **2019**, *535*, 012009.
46. Nousheen, A.; Zia, M.A.; Waseem, M. Exploring Pre-Service Teachers' Self-Efficacy, Content Knowledge, and Pedagogical Knowledge Concerning Education for Sustainable Development. *Environ. Educ. Res.* **2024**, *30*, 321–333.
47. Brown, H.D. *Teaching by Principles: An Interactive Approach to Language Pedagogy*, 4th ed.; Prentice Hall Regents: Englewood Cliffs, NJ, USA, 1994.
48. Braun, V.; Clarke, V. Using Thematic Analysis in Psychology. *Qual. Res. Psychol.* **2006**, *3*, 77–101.
49. Sulastri, S.; Nurkolis, N.; Kusumaningsih, W.; et al. The Quality of Teaching Digitalization in Primary School Context and Its Relationship to Leadership and Work Motivation. *J. Pendidik. Progresif* **2024**, *14*, 1008–1022.
50. Mak, H.W.L.; Han, R.; Yin, H.H. Application of Variational AutoEncoder (VAE) Model and Image Processing Approaches in Game Design. *Sensors* **2023**, *23*, 3457.
51. Wang, S.; Wang, F.; Zhu, Z.; et al. Artificial Intelligence in Education: A Systematic Literature Review. *Expert Syst. Appl.* **2024**, *252*, 124167.
52. Liang, Y.; Jilin, Y.; Han, D. Investigation and Research on the Information-Based Teaching Ability of Pre-Service Teachers from the Perspective of TPACK. *J. Shangrao Norm. Univ.* **2022**, *42*, 77–81. Available online: https://kns.cnki.net/kcms2/article/abstract?v=UKhCRPWaxWbWofeD1IqBW3wrZwwZTyEQLAb6awbQyfrF8ek6GNpP-_lapKJxedwqroBgVjZTYoC-mpC3pz0B0scirvPIH4KIVA5L7SdsrqLA86QjbYSE6X7QwdZDYBLZxyn00UT3uZ0cH52PZe-SeBP3OQL2A7GBkE6MLWftKeEA53usHDoWilhvVFVcujkd (in Chinese).
53. Alelaimat, A.M.; Ihmeideh, F.M.; Alkhawaldeh, M.F. Preparing Preservice Teachers for Technology and Digital Media Integration: Implications for Early Childhood Teacher Education Programs. *Int. J. Early Child.* **2020**, *52*, 299–317. DOI: <https://doi.org/10.1007/s13158-020-00276-2>.
54. Wang, G.; Cao, Y.Y.H.; Sun, W.T.; et al. Visual Analysis of Research Hotspots and Development Trends of Information Technology Competence of Pre-Service Teachers in China under the TPACK Framework. *Qual.-Oriented Educ. West. China* **2025**, *11*, 25–28. DOI: <https://doi.org/10.16681/j.cnki.wcqe.202506006>.
55. Hein, G.E. Constructivist Learning Theory. In Proceedings of the CECA (International Committee of Museum Educators) Conference, Jerusalem, Israel, 15–22 October 1991.
56. Tondeur, J.; Van Braak, J.; Sang, G.; et al. Preparing Pre-Service Teachers to Integrate Technology in Education: A Synthesis of Qualitative Evidence. *Comput. Educ.* **2012**, *59*, 134–144.
57. Lu, L.; Wang, W. Chinese Pre-Service Teachers' Technology Use Experiences and Their Technological Pedagogical Content Knowledge. *Educ. Res. Q.* **2021**, *44*, 34–60.
58. Yang, W.; Wu, D.; Liao, T.; et al. Ready for a Technology Future? Chinese Preservice Preschool Teachers' Technological Pedagogical Content Knowledge and Its Predicting Factors. *J. Res. Technol. Educ.* **2024**, *56*, 655–673.
59. Kosiol, T.; Ufer, S. Teachers' Self-Reported and Actual Content-Related TPACK—New Results on Their Relation and Gender Differences. *Comput. Educ. Open* **2024**, *7*, 100205.
60. Gambari, A.I.; Umahaba, R.E.; Gwoza, M.L.; et al. Influence of Gender on Learning and Behavioural Performances of Undergraduate Pre-Service Teachers Using Mobile Assisted Instruction. *Malays. Online J. Educ. Sci.* **2025**, *13*, 58–71.
61. Navarro, M.; Martin, A.; Gómez-Arízaga, M.P. Profiles of Pre-Service Primary Teachers: Attitudes, Self-Efficacy, and Gender Stereotypes in Teaching Science and Mathematics. *Eurasia J. Math. Sci. Technol. Educ.* **2022**, *18*, em2062.
62. Aziz, A.A.; Rasheed, K. The Influence of Teacher Commitment to Students on Students' Social Development: The Moderating Role of Gender. *Bull. Bus. Econ.* **2024**, *13*, 614–621.
63. John Lorence, V.A. Mobile-Learning Modular App (Molma) for Junior High School Biology: Development, Validation, Perceived Usefulness, and Evaluation. In Proceedings of the 5th International Congress on Action Research, Action Learning (ARAL), Manila, Philippines, 20–22 May 2021.



Copyright © 2026 by the author(s). Published by UK Scientific Publishing Limited. This is an open access article under the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

Publisher's Note: The views, opinions, and information presented in all publications are the sole responsibility of the respective authors and contributors, and do not necessarily reflect the views of UK Scientific Publishing Limited and/or its editors. UK Scientific Publishing Limited and/or its editors hereby disclaim any liability for any harm or damage to individuals or property arising from the implementation of ideas, methods, instructions, or products mentioned in the content.