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Effectiveness of a Collaborative Teaching TPACK Module for Preservice Teachers of English in a Normal University

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Abstract: *Normal Universities (NU) play a crucial role in China's higher education system by preparing preservice teachers who are expected to serve in all levels of the national education system. Although the current curriculum provides a solid foundation in content knowledge (CK) and pedagogical knowledge (PK), preservice teachers often lack systematic support in integrating technology into their teaching practice. The framework of Technological Pedagogical Content Knowledge (TPACK) offers a comprehensive guide for the effective use of educational technology. This study employed a single group pre–posttest quasi-experimental design to evaluate the improvement in overall TPACK and its seven subcomponents among preservice teachers. A paired-samples t-test was conducted to compare the TPACK scores before and after the implementation of the collaborative teaching TPACK module. The results indicated a statistically significant improvement in overall TPACK ($t(57) = 9.521$, $p < .001$, $M = 0.498$, $SD = 0.398$). The largest gains were in TPK (0.793), TCK (0.720), and TK (0.392), with notable increases in PK, CK, PCK, and TPCK. These findings suggest that the collaborative TPACK module is practical for enhancing preservice teachers' technological integration skills and is recommended for broader implementation in teacher education programs.*

Keywords: Technological Pedagogical Content Knowledge (TPACK), English education, technology Integration, Normal University

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1. Introduction

Normal universities (teacher-education universities) play a pivotal role in China's higher education system by preparing preservice teachers for primary, secondary, and vocational settings. These institutions are responsible for developing the knowledge and skills required for effective teaching and learning. Although existing teacher-education curricula provide a solid foundation in content knowledge (CK) and pedagogical knowledge (PK), they often provide limited, practice-oriented support for integrating digital technologies into classroom instruction. As a result, many preservice teachers enter the profession underprepared for technology-enhanced teaching, which highlights the urgent need to explore ways of systematically developing their ability to integrate technology in authentic teaching contexts.

While prior studies (Vasodavan, 2019; Njiku et al., 2021; Backfisch et al., 2023) have demonstrated that collaborative TPACK modules can effectively enhance preservice teachers' technology integration skills, most of this research has been conducted in broader or international contexts. Little is known about how such modules function within the specific setting of Normal Universities in Northwest China. This lack of region-specific evidence raises important questions about how preservice teachers in this area can best be supported in developing technology-enhanced teaching competencies.

The Technological Pedagogical Content Knowledge (TPACK) framework provides a coherent lens for addressing this issue by emphasising the interplay among technology, pedagogy, and content in authentic teaching contexts. However, having a framework alone does not guarantee enactment; what preservice teachers need are learning experiences that operationalise TPACK in collaborative and practice-oriented ways, enabling them to translate conceptual understanding into classroom performance. To respond to this need, the present study introduces and evaluates a collaborative teaching TPACK module—a structured set of learning activities supported by digital collaborative tools, designed to foreground co-planning, peer interaction, and applied practice.

Accordingly, this study investigates whether the module is effective in improving preservice teachers' TPACK as a whole, as well as in strengthening its specific subcomponents (PK, CK, TK, PCK, TPK, TCK, and TPCK). By employing a pre-/post-design, the study aims to provide empirical evidence on the pedagogical value of collaborative teaching TPACK modules in the context of Normal Universities in Northwest China.

Research questions:
1. Is the collaborative teaching TPACK module effective in improving preservice teachers' overall TPACK?
2. Is the module effective in improving preservice teachers' seven TPACK subcomponents (PK, CK, TK, PCK, TPK, TCK, TPCK)?

2. Literature Review

2.1 Collaborative Learning
Collaborative learning (CL) is a generic form of learning which covers a wide range of study methods. With CL, students' contributions to group engagement and subject matter are examined while students cooperate in their knowledge presentation (Riivari et al., 2021). This topic holds considerable weight concerning its positive impact on each party's collaboration regarding teacher and student, student and student. CL is not just for students with lower academic performance; it also positively affects capable students who can enhance knowledge construction and understanding from this collaboration (Kühl et al., 2019). In higher education, CL is implemented through viewpoint exchange within discussion, cooperation, problem-solving, and teamwork (Riivari et al., 2021).

In EFL (English as a Foreign Language) classroom, collaborative tools are effective in a collaborative environment through synchronous and asynchronous communication (Corporan et al., 2020; Hernández-Sellés et al., 2019). They are called Web 2.0 applications because they provide users with the ability to edit plentiful and diverse content and give users chances to spread and post their editing online (Biasutti, 2017).

2.2 Social Constructivism
Social Constructivism is the underpinnings of collaboration in education (Scotland, 2022), and it is used as a guide for content teaching and course development (Pande & Bharathi, 2020). In

Social Constructivism Theory, learning requires active engagement (Mukhalalati & Taylor, 2019; Pande & Bharathi, 2020; Vasodavan et al., 2022), and it involves social and cultural contexts outside of individual learning results concerning both teaching and learning processes, and highlight the inner cognitive process in knowledge construction (Mukhalalati & Taylor, 2019). That is to say, the process of transforming the externally acquired knowledge during discussion to the internal knowledge can be applied by learners (Scotland, 2022). Moreover, a student's knowledge construction is affected by effective interaction with the instructor or more knowledgeable peer, as well as the interaction between new knowledge and previous knowledge of existence (Kühl et al., 2019; Mukhalalati & Taylor, 2019).

2.3 TPACK

Building on these theoretical foundations, the next section explains how the TPACK framework informed the design and implementation of the module. Scholars have traced the origins of the TPACK framework (Lachner et al., 2021; Sarıçoban et al., 2019; Schmid et al., 2021) to Shulman's (1986) conception of Pedagogical Content Knowledge (PCK) (Koehler & Mishra, 2009; Mahmoodi et al., 2021). Shulman (1986) analysed typical problems in teacher education and argued that PCK should be distinguished from other components within the content knowledge domain—namely, Curricular Knowledge and Subject Matter Content Knowledge. Crucially, he emphasised the need to relate pedagogical knowledge (PK) to content knowledge (CK) in teacher preparation (Mishra & Koehler, 2006). To address these issues, Shulman (1986) proposed PCK, defining it as knowledge of strategies that render subject matter comprehensible to learners (p. 9). In practice, PCK requires teachers to interpret content by integrating professional experience with the extant literature and to diagnose and remediate students' misconceptions (Shulman, 1986).

Building on this foundation, subsequent work underscored PCK's contribution to teacher development because it integrates CK and PK to support the organisation, adaptation, and representation of content (Bragg et al., 2021; Mishra & Koehler, 2006). However, the rapid diffusion of educational technologies (e.g., collaborative tools) introduced new possibilities for presenting and representing complex content, while simultaneously exposing a theoretical gap: classroom technologies advanced faster than the frameworks guiding their pedagogical integration (Mishra & Koehler, 2006). This tension—between emergent technologies and the need for principled integration—motivated the expansion from PCK to a technology-inclusive framework.

Accordingly, Mishra and Koehler (2006) articulated the TPCK framework to account for technology integration in teaching and learning. By adding technological knowledge (TK) to the PCK conception, they sought to establish a theoretical basis for educational technology and to foster meaningful technology use (Mishra & Koehler, 2006) (see Figure 1). The core proposition is relational: content, pedagogy, and technology are interdependent and context-sensitive, rather than additive. The framework emerged from a five-year design-development programme (Mishra & Koehler, 2006) that unpacked the key knowledge elements for technology-enhanced instruction and highlighted their complexity and contextuality. Subsequent scholarship adopted the more easily pronounced term "TPACK," popularising the framework globally (Thompson & Mishra, 2007).

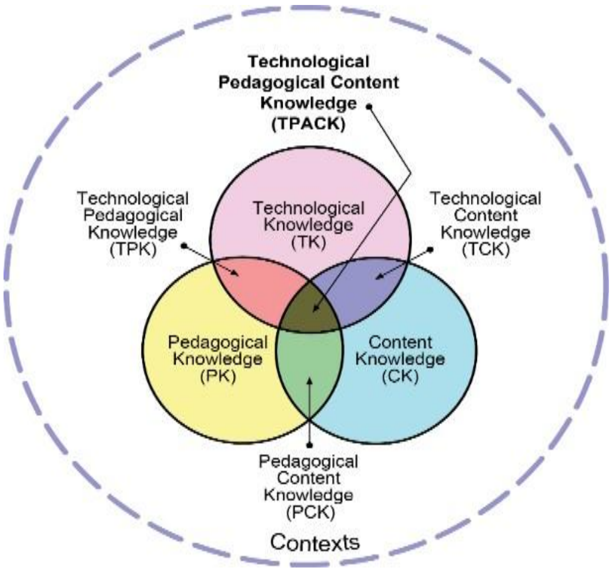

Figure 1: Technological Pedagogical Content Knowledge (TPCK) Framework and its Subconstructs
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Beyond definition, a central question in the literature is how to develop TPACK in practice. Chaipidech et al. (2022) designed a mobile-assisted learning system grounded in andragogy (Knowles et al., 2015), structured into four phases—motivation, conceptualisation, consolidation, and recommendation—and found it effective for in-service teachers: TK, CK, PK, and TCK improved markedly, with modest gains in TPK, PCK, and overall TPACK. Similarly, Lachner et al. (2021) reported gains in TPACK in a subject-specific quasi-experiment but did not observe clear improvements in TPK for the intervention group. Taken together, emerging evidence suggests that while overall TPACK and certain subdomains (notably TCK) are responsive to intervention, TPK often proves more resistant to short-term change.

This pattern aligns with findings on determinants of TPACK enactment. Santos and Castro (2021) indicated that TPK and TCK are key enablers of preservice teachers' application of TPACK. If TCK is comparatively malleable and predicts enactment, then targeted support for TCK becomes a strategic lever for improving technology integration—particularly in preservice contexts where practical enactment is still being formed.

While international studies provide valuable insights, the development and challenges of TPACK in the Chinese teacher-education context reveal both similarities and unique contextual issues. In the Chinese context, composite components (TPK, TCK, PCK) have been shown to exert significant effects on overall TPACK (Zhao, 2023). A qualitative study by Wei, Hu, and Yu (2021), using MOOC development as an intervention with in-service teachers, found that TCK improved noticeably, whereas TPK and PCK were harder to develop—a pattern resonant with international findings (Lachner, 2021; Chaipidech et al., 2022). Literature reviews further highlight systemic challenges: limited intrinsic motivation for self-regulated professional learning, an overreliance on lecture-based training rather than learning-by-design, insufficient subject-specific training, and misalignment with teachers' actual needs (Yu, 2020; Yu & Zhu, 2019). These constraints help explain why some TPACK subdomains—especially TPK—lag despite exposure to technology.

2.4 Synthesis and Rationale for the Present Study

The literature thus converges on two needs: (a) practice-oriented, context-sensitive learning designs that move beyond exposition to enactment, and (b) targeted strengthening of subdomains most predictive of classroom application, particularly TCK (with attention to the persistent challenge of TPK). Responding to these needs, the present study implements a collaborative teaching TPACK module that leverages digital collaborative tools to embed co-planning, peer interaction, and applied practice. This design aims to enhance preservice teachers' overall TPACK and its seven subcomponents, and the study empirically evaluates the module's effectiveness through pre–post measurement.

In response to these identified needs and challenges, the present study employs a quasi-experimental, one-group pretest–posttest design to evaluate the effectiveness of a collaboratively designed TPACK module, as detailed in the Methodology.

3. Methodology

To evaluate the impact of this module, a quasi-experimental design was employed, as outlined below.

3.1 Research Design

To evaluate the impact of this module, a quasi-experimental design was employed, as outlined below. This study employed a single-group pretest–posttest quasi-experimental design to evaluate improvements in preservice teachers' overall TPACK and its seven subcomponents. This design is widely used in module evaluation because it allows examination of within-group change following an instructional intervention. Accordingly, a paired-samples t-test was conducted to compare pre- and post-implementation TPACK scores for the collaborative teaching TPACK module.

As shown in Figure 2, a one-group pretest–posttest design involves measuring the same participants before (O_1) and after (O_2) the intervention (X). In this study, O_1 represents participants' baseline TPACK and their use of digital collaborative tools prior to the module, X denotes the collaborative teaching TPACK module developed as the intervention and O_2 represents the same outcomes measured after the intervention.

O_1	X	O_2
Pretest	Treatment: The collaborative teaching TPACK module	Posttest
(dependent variable)		(dependent variable)

Figure 2: Illustration of the Single-Group Pre- and Post-test Quasi-Experiment

3.2 Rationale for a Quasi-Experimental Approach

A quasi-experiment, rather than a true experiment, was appropriate because random assignment was not feasible in the natural instructional context; instead, intact classes were used (Cohen et al., 2007; Creswell, 2012). Consistent with Creswell and Creswell (2018), this constitutes an experiment without random assignment, which is common in educational settings where existing cohorts must be preserved.

3.3 Population and Sample

The target population comprised approximately 300 preservice teachers enrolled in the English program at a normal university in China. The focal group included third- and fourth-year students awaiting internship or graduation. From this population, the analytic sample consisted of 58 preservice teachers from two administrative classes.

3.4 Sample Size Determination

For a t-test of two dependent means (matched pairs), a minimum of 27 participants is typically recommended. The present study's N = 58 therefore exceeds this threshold. This sample size applies both to the post-survey of TPACK and to the pre- and post-tests on the integration of digital collaborative tools.

3.5 Sampling Method and Ethical Procedures

A purposive sampling strategy was used, which is suitable for obtaining information-rich cases in intensive instructional contexts (Richey & Klein, 2007). Ethical clearance was granted by the University Ethics Committee. During the orientation session and prior to implementation, participants accessed the Rain Classroom platform to complete the pretest on current use of collaborative tools. They also received the module outline, the module purpose, and the researcher's contact information. Information sheets and consent forms clarified the nature of the data to be collected, anonymity procedures, and participants' right to withdraw at any time. Installation guidance for digital collaborative tools was provided based on experts' validation. Once the sample was confirmed and ethical clearance obtained, the intervention was implemented as follows.

3.6 Instrument

The TPACK.xs questionnaire (Schmid et al., 2020) comprised 27 items across seven subscales (PK, CK, TK, PCK, TPK, TCK, TPCK), rated on a 7-point Likert scale (1 =strongly disagree, 7 =strongly agree). In this study, Content validity was established via expert review and back-translation procedures.

3.7 Intervention Procedures

The collaborative teaching TPACK module was implemented over approximately one and a half months with a total duration of 18 hours and 10 minutes. This included a 50-minute orientation, four lessons (each 1 hour 14 minutes), a 2-hour peer-teaching assessment, and an additional 8 hours 40 minutes of self-regulation work (i.e., independent study and peer-teaching preparation). The module instructor was the course teacher in the program (not the researcher). The module was embedded in the last two units of "English Subject Curriculum and Instructional Design" (Teaching Listening and Speaking). During implementation, preservice teachers engaged with content related to the TPACK framework, First Principles of Instruction, taxonomy of learning outcomes, and the use of digital collaborative tools (e.g., AI, VR, microblogging, instant messaging, short video, and learning management systems), along with other technologies relevant to English listening and speaking. The collaborative nature of the module was enacted through peer teaching, group discussion, lesson-plan design, and peer assessment using collaborative tools.

3.8 Post-Intervention Data Collection and Analysis

After implementation, participants completed the TPACK survey via the Wen Juan Xin mini-program in WeChat. These data were used to assess changes in preservice teachers' TPACK and their use of collaborative tools. The TPACK pre- and post-survey were analysed in SPSS using paired-samples t-tests to determine whether statistically significant improvements occurred, thereby enabling conclusions about the module's effectiveness.

4. Results and Discussion

4.1 The Effectiveness of the Module on Improving EFL Preservice Teachers' TPACK

In order to answer the first research question: Is the collaborative teaching TPACK module effective in improving preservice teachers' TPACK? This study utilised a pre- and post-TPACK.xs survey to demonstrate the differences in scores before and after the module implementation. Besides, a Peer Teaching Score Based on the Evaluation Rubric, was also used as a supplement to the analysis. Before analysing the pre- and post-TPACK.xs surveys, a normality test was conducted to determine the analysis method for comparing the pre- and post-surveys.

4.1.1 Normality Test for Pre and Post TPACK.xs Survey

This study employed analytical and graphical methods to assess the normality of the TPACK.xs survey as presented in Table 1. The null hypothesis is that a normal distribution is assumed.

Table 1: Test for Normality of Pre and Post TPACK.xs Survey

Tests of Normality	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
pre survey	.085	58	.200*	.984	58	.622
post survey	.132	58	.014	.967	58	.113

Note: *. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Regarding the results of the presurvey (0.622) and post-survey (0.113), both p-values were bigger than 0.05, as can be seen from Table 1. So, the researcher failed to reject the null hypothesis, and the normal distribution is assumed. Thus, the result is sufficiently normal for a statistical test, such as a t-test.

4.1.2 T-Test Result from the Pre and Post-TPACK. xs Survey

The data were then analysed using a t-test (see Tables 2, 3 and 4), as well as a Wilcoxon matched pairs signed-rank test, because it was considered that a non-parametric signed-rank test would usefully supplement and extend the t-test results. The null hypothesis is that the collaborative teaching TPACK module does not improve the TPACK of EFL preservice teachers.

Table 2 presents the mean and standard deviation for both the pre-TPACK and post-TPACK. xs survey. Before the module implementation, preservice teachers had a mean score of M = 4.12, SD = 1.025, and after the implementation, M = 4.61, SD = 0.687. As shown in Table 4, the mean difference between the pre- and post-scores was M = 0.498, SD = 0.398. A paired samples t-test revealed a significant difference between the two time points, $t(57) = 9.521$, $p < 0.001$. Thus, the researcher rejected the null hypothesis, suggesting that the module implementation had a significant influence on participants' scores. Notably, the collaborative teaching TPACK module improved participants' performance of TPACK.

Table 2: Paired Samples Statistics in T-TEST of Pre and Post TPACK.xs Survey

	Mean	N	Std. Deviation	Std. Error Mean
TPACK pre	4.12	58	1.025	.135
TPACK post	4.61	58	.687	.090

Table 3: Paired Samples Correlations in T-TEST of Pre and Post TPACK.xs Survey

	N	Correlation	Significance	
			One-Sided p	Two-Sided p
TPACK pre & TPACK post	58	.969	<.001	<.001

Table 4: Paired Samples Test in T-TEST of Pre and Post TPACK.xs Survey

	Paired Differences					t	df	Significance	
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				One-Sided p	Two-Sided p
				Lower	Upper				
TPACK pre-TPACK post	-.498	.398	.052	-.603	-.393	-9.521	57	<.001	<.001

Further analysis of the Wilcoxon Signed Ranks Test (see table 5 and table 6) also confirmed the module's effectiveness in terms of TPACK. The Wilcoxon matched pairs signed-rank test showed that the median post-TPACK survey score (*Md* = 4.55) was statistically higher than the median pre-TPACK survey score (*Md* = 4.05), $z = -6.355$, $p < .001$, and the increase was large ($r = -.84$).

Table 5: Results from the Wilcoxon Signed Ranks Test

	TPACK post - TPACK pre
Z	-6.355^b
Asymp. Sig. (2-tailed)	<.001

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

Table 6: Median of the Pre- and Post-TPACK. xs survey

	N	Mean	Std. Deviation	Percentiles		
				25	50	75
TPACK pre	58	4.12	1.03	3.54	4.05	4.82
TPACK post	58	4.61	.69	4.18	4.55	5.14

The results from both the t-test and the Wilcoxon Signed Ranks Test suggest that this collaborative teaching TPACK module has a statistically significant effect on preservice teachers' TPACK.

4.1.3 Preservice Teachers' Peer Teaching Score Based on the Evaluation Rubric

To supplement the questionnaire data, peer teaching was conducted to demonstrate how well the module was likely to advance preservice teachers' TPACK. All student responses and module outcomes were evaluated by a single rater (the instructor) due to practical constraints. A rubric (see Appendix) was used to rate the peer teaching performance, assessing how well the integration of digital collaborative tools (technological knowledge) aligned with English listening and speaking (Content knowledge) and instructional strategies (pedagogical knowledge).

Table 7 and Table 8 present the two classes of preservice teachers' peer teaching assessment scores based on the evaluation rubric. There are six groups in each class, and the instructor gives the final score.

Table 7: Preservice Teachers' Peer Teaching Score Based on the Evaluation Rubric (Class One)

Criteria	Preservice Teachers' Peer Teaching Score (%)					
	1	2	3	4	5	6
Curriculum Goals & Technologies (Curriculum-based technology use) (TCK)	25	25	18.75	25	25	25
Instructional Strategies & Technologies (Using technology in teaching/ learning) (TPK)	25	25	25	25	25	25
Technology Selection(s) (Compatibility with curriculum goals & instructional strategies) (TK, TPACK)	25	25	18.75	25	18.75	25
"Fit" (Content, pedagogy and technology together) (TPACK)	25	25	25	25	25	25
Total Score	100	100	87.5	100	93.75	100

Table 8: Preservice Teachers' Peer Teaching Score Based on the Evaluation Rubric (Class Two)

Criteria	Preservice Teachers' Peer Teaching Score (%)					
	1	2	3	4	5	6
Curriculum Goals & Technologies (Curriculum-based technology use) (TCK)	25	18.75	18.75	25	18.75	25
Instructional Strategies & Technologies (Using technology in teaching/ learning) (TPK)	25	25	18.75	25	25	25
Technology Selection(s) (Compatibility with curriculum goals & instructional strategies) (TK, TPACK)	25	25	18.75	25	18.75	25
"Fit" (Content, pedagogy and technology together) (TPACK)	25	18.75	18.75	25	25	25
Total Score	100	87.5	75	100	87.5	100

According to Tables 7 and 8, eight out of twelve groups of EFL preservice teachers can choose technologies in their peer teaching that are strongly aligned with one or more curriculum goals. By contrast, one-third of the presentation groups are only able to find technologies that just meet the requirements of the curriculum goals according to the rubric.

Considering the second criterion, surprisingly, strong evidence of preservice teachers' TPK ability was found in their peer teaching demonstration. Eleven out of twelve groups demonstrated their ability to integrate technology that optimally supports instructional strategies, while only one group managed to use technology to support instructional strategies.

Next, the third criterion, nine preservice teacher groups demonstrated an exemplary choice of technology in alignment with their teaching objectives and instructional strategies. One-third of groups were only able to appropriately select technology based on the teaching objectives and instructional strategies.

Finally, in the fourth criterion, five-sixths of preservice teacher groups demonstrated the ability to apply their PK, CK, and TK flexibly. In their peer teaching, the content, instructional strategies and technology fit strongly together. However, only one-sixth of the group meet the basic requirement, and their content, instructional strategies, and technology fit together within their peer teaching.

In summary, the results from pre- and post-TPACK.xs surveys and the peer teaching assessment provide essential insights into using a collaborative teaching TPACK module to improve EFL preservice teachers' TPACK effectively.

4.2 The Findings from the TPACK Subconstructs in Pre and Post Survey

Prior to conducting the paired-sample t-tests, the normality assumption was first examined using both the Kolmogorov–Smirnov and Shapiro–Wilk tests. As shown in Table 9, most variables met the normality assumption (p > .05) according to the Shapiro–Wilk test, which was taken as the primary reference given the relatively small sample size (N = 58). Although a few variables (e.g., post-TCK, post-TPCK) approached the threshold of significance, the majority of the pre- and post-test distributions satisfied the assumption of normality. Given N = 58, the Shapiro–Wilk test was taken as the primary reference for normality. This indicates that parametric statistical tests were appropriate for further analysis.

Table 9: Normality Test for Seven TPACK subconstructs

Tests of Normality	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
pre PK average	.083	58	.200*	.982	58	.543
post PK average	.116	58	.050	.971	58	.187
pre CK average	.077	58	.200*	.990	58	.930
post ck average	.127	58	.021	.977	58	.330
pre TK average	.126	58	.023	.980	58	.469
post TK average	.099	58	.200*	.974	58	.239
pre PCK average	.087	58	.200*	.983	58	.566
post PCK average	.087	58	.200*	.988	58	.841
pre TPK average	.106	58	.159	.975	58	.280
post TPK average	.115	58	.054	.963	58	.073
pre TCK average	.158	58	<.001	.961	58	.060
post TCK average	.143	58	.005	.964	58	.082
pre TPCK average	.165	58	<.001	.978	58	.355
post TPCK average	.143	58	.005	.964	58	.082

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Subsequently, paired-samples t-tests were conducted to compare preservice teachers' pre- and post-test scores across the seven TPACK subcomponents (Table 10). Results revealed statistically significant improvements in all dimensions after the intervention. Negative values indicate higher post-test scores. Specifically, preservice teachers demonstrated significant gains in Pedagogical Knowledge (PK), Content Knowledge (CK), Technological Knowledge (TK), Pedagogical Content Knowledge (PCK), Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), and Technological Pedagogical Content Knowledge (TPCK). The observed t values ranged from –4.82 to –7.36, with all differences reaching the level of high statistical significance (p < .001).

Table 10: Paired Samples Test in T-TEST of the subcomponents of TPACK in Pre and Post Survey

	Paired Differences					t	df	Significance	
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				One-Sided p	Two-Sided p
				Lower	Upper				
pre PK average - post PK average	-.27586	.43601	.05725	-.39051	-.16122	-4.818	57	<.001	<.001
pre CK average - post ck average	-.26724	.35313	.04637	-.36009	-.17439	-5.764	57	<.001	<.001
pre TK average - post TK average	-.39224	.42948	.05639	-.50517	-.27931	-6.955	57	<.001	<.001
pre PCK average - post PCK average	-.25862	.34719	.04559	-.34991	-.16733	-5.673	57	<.001	<.001
pre TPK average - post TPK average	-.79310	.86366	.11340	-1.02019	-.56601	-6.994	57	<.001	<.001
pre TCK average - post TCK average	-.71983	.74498	.09782	-.91571	-.52395	-7.359	57	<.001	<.001
pre TPCK average - post TPCK average	-.64655	.88113	.11570	-.87823	-.41487	-5.588	57	<.001	<.001

In addition to statistical significance, paired-sample correlations demonstrated very strong associations (r = 0.94–0.96) between pre- and post-test scores in PK, CK, TK, and PCK, suggesting that participants' baseline levels were consistently improved through the intervention. Meanwhile, moderately strong correlations (r = 0.66–0.75) were observed in TPK, TCK, and TPCK, which further highlights the transformative impact of the module in reshaping teachers' perceptions and practices regarding technology integration.

Taken together, these findings suggest that the collaborative teaching TPACK module exerted a substantial positive influence on preservice teachers' professional competencies, with particularly pronounced effects in the technological knowledge integration domains. This underscores the value of embedding collaborative, technology-enhanced pedagogical training in teacher education programs at Normal Universities.

These findings provide initial evidence of the module's effectiveness. The following discussion interprets these results in light of previous research and explores their implications for preservice teacher education.

These findings not only confirm the effectiveness of the collaborative teaching TPACK module but also raise important questions about how and why certain subdomains, such as TPK, developed differently from those reported in earlier literature; the discussion section elaborates on these issues.

4.3 Discussion

Regarding the module effectiveness, this study found that the collaborative teaching TPACK module has significantly improved preservice teachers' TPACK. This result agrees with the findings of other studies (Vasodavan, Dewitt, & Alias, 2020; Chaipidech et al., 2022; Wei, Hu, & Yu, 2021). It is reported that a collaborative TPACK approach enhanced instructors' TPACK (Vasodavan, Dewitt, & Alias, 2020), especially their confidence in integrating TPACK into instruction, the improvement of awareness about the opportunities for using TPACK, and the enhancement of strategies and perceptions of effective TPACK instruction. Similarly, this finding is broadly in agreement with the findings of Chaipidech et al. (2022) and Wei, Hu & Yu (2021). According to Chaipidech et al. (2022), the mobile-assisted learning system, which aims to support personalised TPACK training, proved effective in promoting in-service teachers' TPACK, especially their TK, CK, PC, and TCK. Furthermore, MOOC development intervention enhanced in-service teachers' TPACK, especially TCK.

Interestingly, while prior studies frequently reported that TPK was one of the most difficult subdomains of TPACK to improve, the present study revealed a notable growth in TPK. According to previous literature, the constraints in the development of Technological Pedagogical Knowledge (TPK) may account for the fact that although preservice teachers were provided with opportunities to engage with digital technologies, the effective integration of these tools into pedagogical practices requires a more complex set of skills than mere exposure. In other words, while participants could acquire technological knowledge (TK) itself more readily, transforming this knowledge into pedagogically sound strategies (TPK) demands deeper reflection, sustained practice, and contextualized support. This explains why TPK, compared with other subdomains, demonstrated comparatively slower growth despite technology-enhanced learning opportunities (Yu, 2020; Yu & Zhu, 2019). However, the current investigation employed a specific designed collaborative teaching TPACK module, which emphasized co-planning, peer interaction, and applied practice in authentic EFL classroom contexts. Such collaborative and contextualized tasks may have provided preservice teachers with concrete opportunities to experiment with integrating technology into pedagogy, thereby overcoming one of the challenges highlighted in earlier research. These findings suggest that collaborative and practice-oriented approaches may be particularly effective in fostering the development of TPK, a dimension that has traditionally been regarded as resistant to change. The design of the module also helped to make the development of TPK more tangible and practice oriented. For instance, in the peer evaluation tasks, preservice teachers were explicitly required to provide comments on the "technology–strategy match" within their peers' lesson plans. This operationalized the abstract dimension of TPK into a concrete evaluative activity, encouraging preservice teachers to reflect critically on how specific technologies align with pedagogical strategies and learning objectives.

5. Conclusion

This study set out to evaluate a collaborative teaching TPACK module aimed at enhancing preservice EFL teachers' ability to integrate technology into their teaching practice. Drawing on the TPACK framework and grounded in a design and development research (DDR) approach, the module foregrounded co-planning, peer interaction, and applied practice in technology-enhanced pedagogy. The findings demonstrated measurable improvements in preservice teachers' overall TPACK as well as specific subcomponents, suggesting that targeted, collaborative interventions can bridge the persistent gap between theoretical knowledge and classroom application.

These findings suggest that the collaborative TPACK module is practical for enhancing preservice teachers' technological integration skills and is recommended for broader implementation in teacher education programs. Taken together, the evidence underscores the potential of collaborative teaching modules for strengthening preservice teachers' TPACK, thereby addressing a longstanding challenge in teacher preparation: the difficulty of translating technological knowledge into pedagogical practice.

There are three main limitations to this study. First, the implementation phase was exploratory in nature, as the primary aim was to develop and pilot the collaborative teaching TPACK module, which differs substantially from traditional courses in this context. Consequently, the study did not include a control group receiving conventional teaching, which limits the ability to make direct comparisons. Future studies should include multi-site samples and objective performance-based measures to mitigate common-method bias, and test whether cohort-level covariates (e.g., year of study) moderate gains in TPK. Second, the research focused exclusively on preservice teachers, whereas further studies are needed to explore how in-service teachers perceive and apply TPACK in practice. Moreover, one limitation of the study is that all student responses and module outcomes were evaluated by a single rater due to practical constraints. While this approach ensured consistency in scoring, it inevitably limited inter-rater reliability. To strengthen the validity and reliability of the findings, future research should involve multiple raters and establish inter-rater agreement as part of the evaluation process.

Despite these limitations, the collaborative teaching TPACK module holds promise. It not only enriches preservice teachers' understanding of technology integration but also demonstrates the feasibility of embedding such modules into existing curricula. Therefore, it is recommended for adoption in Normal Universities in northwest China and beyond, as a viable pathway to cultivate preservice EFL teachers who are confident and competent in technology-enhanced pedagogy. Future research should extend this line of inquiry to in-service teachers and include controlled comparisons to further validate the module's effectiveness.

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Conflict of Interest Statement
The authors declare that there is no conflict of interest regarding the publication of this study.

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Appendix: Assessment Rubric for Peer Teaching

Criteria	4	3	2	1
Curriculum Goals & Technologies (Curriculum-based technology use) **(TCK)**	Technologies selected for use in the instructional plan are strongly aligned with one or more curriculum goals.	Technologies selected for use in the instructional plan are aligned with one or more curriculum goals	Technologies selected for use in the instructional plan are partially aligned with one or more curriculum goals	Technologies selected for use in the instructional plan are not aligned with any curriculum goals.

Instructional Strategies & Technologies (Using technology in teaching/ learning) **(TPK)**	Technology use optimally supports instructional strategies.	Technology use supports instructional strategies.	Technology use minimally supports instructional strategies.	Technology use does not support instructional strategies.
Technology Selection(s) (Compatibility with curriculum goals & instructional strategies) **(TK, TPACK)**	Technology selection(s) are exemplary, given curriculum goal(s) and instructional strategies.	Technology selection(s) are appropriate, but not exemplary, given curriculum goal(s) and instructional strategies.	Technology selection(s) are marginally appropriate, given curriculum goal(s) and instructional strategies.	Technology selection(s) are inappropriate, given curriculum goal(s) and instructional strategies.
"Fit" (Content, pedagogy and technology together) **(TPACK)**	Content, instructional strategies and technology fit together strongly within the instructional plan.	Content, instructional strategies and technology fit together within the instructional plan.	Content, instructional strategies and technology fit together somewhat within the instructional plan.	Content, instructional strategies and technology do not fit together within the instructional plan.

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