Revista Latinoamericana de Tecnología Educativa, 25(2)
https://doi.org/10.17398/1695-288X.25.2.181

RELATEC
Revista Latinoamericana de Tecnología Educativa

ARTICLE / ARTÍCULO

Development of TPACK among Pre-Service EFL Teachers: Cooperative Learning Readiness

Desarrollo del TPACK en futuros docentes de inglés como lengua extranjera: disposición hacia el aprendizaje cooperativo.

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Received: September 21, 2025
Revised: April 15, 2026
Accepted: April 29, 2026

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Abstract: Effective technology integration in English as a Foreign Language (EFL) instruction requires pre-service teachers to develop robust Technological Pedagogical Content Knowledge (TPACK) frameworks to incorporate technology in EFL instruction. However, effectively improving this integrative knowledge poses a persistent challenge in pre-service teacher education, particularly in resource-limited settings. The present study sought to evaluate the role of cooperative readiness, which is considered as the preparedness to cooperate and adapt within a group in progressing TPACK among Iranian pre-service EFL teachers enrolled in final-year programs at three public teacher training institutions in Tehran. In this explanatory sequential mixed-methods study, the quantitative phase included 120 pre-service teachers who completed validated scales evaluating TPACK and cooperative readiness. The results indicated that cooperative readiness is a significant predictor of TPACK, explaining a substantial share of its variance. The qualitative phase including semi-structured interviews with 15 participants provided deeper insights into this relationship. Thematic analysis identified three key mechanisms through which collaboration fosters the development of TPACK by facilitating the dialogic co-construction of integrative knowledge through peer negotiation and reflection, alleviating technological anxiety and creating a supportive environment for experimentation, and adapting theoretical knowledge to real-world classroom constraints by serving as a bridge. Empirically, the findings indicated the synergistic relationship between collaborative competence and technological-pedagogical expertise, while practically suggesting that teacher education programs should extend beyond standalone technology courses and deliberately design collaborative learning experiences to effectively prepare pre-service teachers for the demands of technology-integrated language instruction.

Keywords: Preservice Teacher Education, English (Second Language), Second Language Instruction, Cooperative Learning, Technology Integration, Mixed Methods Research, TPACK.

Resumen: La integración efectiva de la tecnología en la enseñanza del inglés como lengua extranjera (EFL) requiere que los futuros docentes desarrollen marcos sólidos de Conocimiento Tecnológico Pedagógico del Contenido (TPACK) para incorporar tecnología en la instrucción de EFL. Sin embargo, mejorar eficazmente este conocimiento integrador plantea un desafío persistente en la formación inicial docente, especialmente en entornos con recursos limitados. El presente estudio buscó evaluar el papel de la disposición cooperativa, entendida como la preparación para cooperar y adaptarse dentro de un grupo, en el progreso del TPACK entre futuros docentes iraníes de EFL matriculados en programas de último año en tres instituciones públicas de formación docente en Teherán. En este estudio de métodos mixtos de diseño secuencial explicativo, la fase cuantitativa incluyó a 120 futuros docentes que completaron escalas validadas para evaluar su TPACK y disposición cooperativa. Los resultados indicaron que la disposición cooperativa es un predictor significativo del TPACK, explicando una proporción sustancial de su varianza. La fase cualitativa, que incluyó entrevistas semiestructuradas con 15 participantes, proporcionó una comprensión más profunda de esta relación. El análisis temático identificó tres mecanismos clave a través de los cuales la colaboración fomenta el desarrollo del TPACK: facilitando la co-construcción dialógica del conocimiento integrador mediante la negociación y reflexión entre pares, aliviando la ansiedad tecnológica y creando un entorno propicio para la experimentación, y adaptando el conocimiento teórico a las restricciones reales del aula al servir como puente. Empíricamente, los hallazgos evidenciaron la relación sinérgica entre la competencia colaborativa y la experiencia tecnológico-pedagógica, mientras que, desde una perspectiva práctica, sugieren que los programas de formación docente deben trascender los cursos aislados de tecnología y diseñar deliberadamente experiencias de aprendizaje colaborativo para preparar eficazmente a los futuros docentes ante las exigencias de la enseñanza de idiomas integrada con tecnología.

Palabras-clave: Formación inicial del profesorado, Inglés como lengua extranjera, Enseñanza de segundas lenguas, Aprendizaje cooperativo, Integración de la tecnología, Investigación de métodos mixtos, TPACK.

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1. Introduction

The widespread integration of technology has fundamentally transformed contemporary teaching and learning paradigms. Digital instruments are currently utilized in educational contexts, providing enhanced accessibility and user-friendly interactions (Mexhuani, 2025). However, the influence of such technologies on enhancing student learning requires further investigation (Kosmas & Zaphiris, 2023). In EFL settings, this integration is often achieved through Computer-Assisted Language Learning (CALL), which applies mobile applications, online platforms, and virtual environments to create more continuous, collaborative, and reflective learning experiences (Zain & Bowles, 2021).

Integrating technology into the classroom remains a significant concern for teachers. Teachers should learn to work with digital instruments during their teaching, highlighting the significance of the Technological Pedagogical Content Knowledge (TPACK) framework (Tseng et al., 2022). This model proposes that effective technology incorporation requires a synergistic interplay between Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK). The absence of any single component may lessen teaching efficacy. Research consistently positions, TPACK is considered a vital determinant of teacher preparedness in technology-rich classrooms (Li, 2025).

This phenomenon holds significance in milieus such as Iran, where educators often struggle with reconciling traditional methodologies with digital innovations and where infrastructural constraints significantly shape technology adoption patterns (Karbalaei, 2025). Additionally, reflective practice and accumulated classroom experience are essential to nurture the organic development of TPACK (Maor, 2017).

Despite the inclusion of educational technology courses in teacher training programs, a critical gap remains regarding how cooperative readiness—conceptualized as the preparedness to cooperate and adjust within a group—influences the development of TPACK among pre-service EFL teachers (Belda-Medina & Calvo-Ferrer, 2022). The potential interdependence of such constructs has not been empirically examined, despite theoretical suggestions. This connection plays a crucial role, as collaboration during group instruction and practicum experiences may improve pre-service teachers' flexibility and self-efficacy in employing technology to develop authentic instructional scenarios (Gurvitch & Metzler, 2009).

This dynamic is particularly salient in developing nations such as Iran, where educational technology remains unevenly distributed. The continued reliance on traditional instructional methods by in-service teachers, often stemming from insufficient training or resources, creates an environment where collaborative learning among teacher candidates proves crucial (Ouyang et al., 2021).

Pre-service teachers who engage in teamwork can cooperatively overcome anxieties, exchange innovative ideas, and identify meaningful applications for technology (Kim, 2025; Ottenbreit-Leftwich et al., 2012). This study seeks to examine the role of cooperative readiness in advancing TPACK among prospective EFL teachers, filling a gap in understanding collaboration dynamics within the TPACK model in EFL teacher education.

The TPACK framework builds on Shulman's (1986) concept of Pedagogical Content Knowledge (PCK), which highlights that effective teaching involves transforming subject matter knowledge into pedagogically meaningful forms adapted to the needs of diverse learners. The digital era has extended this knowledge to include technology. However, resistance to technology adoption continues due to cultural factors, inadequate professional development, or skepticism about the efficacy of digital learning (Abbasi Kasani et al., 2020). Obstacles such as scarce training, poor infrastructure, and the absence of modern devices further inhibit enactment.

While student feedback and blended learning models offer promising pathways for integration (Benade, 2015; Singh et al., 2021), enacting these approaches within the education context of Iran is impeded by unfamiliarity with LMS platforms and infrastructural insufficiencies (Chenari et al., 2024). Critically, teacher education programs rarely provide integrated training that links technological proficiency with collaborative pedagogical reflection—a combination essential for success in modern classrooms.

Drawing on evidence from STEM and language education, technological confidence, coupled with collaborative and reflective practices, emerges as a key conditioning factor for robust TPACK development (Chai, 2018; Yildiz Durak et al., 2023). The present study aims to address this gap by probing the juncture of cooperative readiness and TPACK within Iranian EFL teacher education. By elucidating this relationship, the results can inform the design of more effective training programs which prepare teachers for technologically constrained settings. Training pre-service teachers with collaborative and technological skills signifies an essential step toward nurturing educational quality (Lim et al., 2011).

Ultimately, this research offers actionable insights for curriculum designers, teacher educators, and policymakers in Iran, advocating for an integrated, socially embedded approach to teacher development. The following questions are applied to explore the issue through quantitative and qualitative research approaches within a mixed-methods design: (1) To what extent does cooperative readiness predict TPACK among pre-service EFL teachers? (2) How do pre-service teachers perceive that collaborative experiences facilitate the development of their TPACK?

1.1. Literature review

Incorporating technology into EFL pedagogy has catalyzed a significant shift in instruction and learning methodologies. This study synthesizes current scholarship to identify the key factors that condition TPACK development in initial teacher education, with particular emphasis on cooperative readiness as a socially embedded catalyst.

Technological Frameworks and TPACK Development in Initial Teacher Education

The current EFL classroom is progressively characterized by the integration of digital instruments such as mobile applications, LMS, and virtual simulations. These resources potentially boost flexibility, interactivity, and learner engagement by facilitating self-paced learning beyond the restrictions of the physical classroom (Ahmed et al., 2025). However, the efficacy of such instruments, especially for novice learners, remains a point of scholarly dispute. Research indicates that novice teachers require heightened

autonomy and digital literacy to apply these tools effectively, otherwise technology may hinder rather than enhance motivation and comprehension (Ting, 2015).

Teachers can use CALL to teach different instructional aspects, from grammar to conversation, through Mobile-Assisted Language Learning (MALL), virtual reality platforms, and AI-driven chatbots (Solak, 2024). This expansion supports basic Second Language Acquisition (SLA) theories, which include constructivism, sociocultural theory, and interactionist approaches, highlighting knowledge construction through meaningful social interaction, reflection, and authentic contextual learning.

Mishra and Koehler (2006) presented the TPACK framework, building on Shulman's (1986) concept of PCK to offer a structured approach for teachers exploring this complex landscape. TPACK indicates that effective technology incorporation requires an integrative and reflexive awareness of the relationship between CK, PK, and TK. This fundamental model was later advanced into seven interconnected constituents, where TPK, TCK, and PCK coalesce to form the comprehensive TPACK needed for effective instruction (Tseng et al., 2022).

Empirical studies confirm that self-efficacy and pedagogical reasoning strongly predict TPACK proficiency, suggesting that technical access alone is insufficient without structured developmental support (Yildiz Durak et al., 2023). Although blended learning models have demonstrated promise in enhancing student engagement (Singh et al., 2021), their implementation in contexts like Iran remains constrained by infrastructural limitations and insufficient preparatory training (Chenari et al., 2024).

Teacher readiness, reflection, and imperative for collaboration

The successful application of technological frameworks depends heavily on the teacher, despite their potential to offer an essential structure. Studies propose a persistent gap between technological access and instructional application (Looker, 2010). For example, research in EFL settings revealed that even teachers with strong subject matter knowledge often lack the confidence to effortlessly integrate technology into their lessons (Aydin, 2013), indicating that holding knowledge of technology differs from possessing the knowledge to teach efficiently with technology.

Such a gap highlights the sustained significance of Shulman's (1986) PCK concept, which underscores the transformation of CK into instructionally powerful forms adjusted to student needs. Recent applications of the Refined Consensus Model (RCM) demonstrate that effective teachers develop this integrative knowledge through continuous reflection and peer-supported classroom experimentation, rather than isolated skill acquisition (Carlson et al., 2019; Rojo et al., 2024).

To bridge the gap between theory and practice, scholars emphasize the significance of enhancing cooperative readiness, conceptualized as a teacher's preparedness to collaborate, exchange ideas, and adjust within a professional community (Matsko et al., 2020)— a dynamic particularly salient in Iranian EFL contexts, where prior research documents how collaborative scaffolding mediates technology integration amid resource constraints. Because TPACK is fundamentally a socially constructed and context-dependent framework, its development thrives on reflective dialogue and collaborative practice rather than isolated technical training. Training programs, which separate technological skills from collaborative and

instructional reflection, fail to prepare teachers for the realities of the classroom (Quintana & Fernández, 2015). Bañados (2006) argued that incorporating training on collaboration with technology plays a vital role for success in blended or online milieus. Pre-service teachers participating in teamwork during practicum or group projects build the flexibility and mutual problem-solving skills essential to overcome technological and teaching challenges, thereby directly strengthening their overall TPACK.

Synthesizing the literature, digital tools and TPACK frameworks lack transformative power when deployed in isolation (Maor, 2017; Tseng et al., 2022). Transforming EFL instruction, especially in resource-constrained settings, requires intentional pedagogical design. Teachers should be armed with integrative frameworks while developing their competence for cooperation, reflection, and adaptive practice. Consequently, teacher education programs must be deliberately structured to interweave technological training with sustained collaborative inquiry, thereby cultivating practitioners who are both technologically proficient and pedagogically responsive (Kim, 2025; Ottenbreit-Leftwich et al., 2012).

2. Methodology

This study employed a mixed-methods approach was selected to explore the relationship between cooperative readiness and TPACK among Iranian pre-service EFL teachers. The explanatory sequential design was adopted, encompassing a two-stage approach in which quantitative data collection and analysis informed a subsequent qualitative phase intended to expand, clarify, and contextualize the initial numerical results. This approach was selected to systematically identify statistical patterns while simultaneously elucidating the underlying meanings and lived experiences of the participants.

The quantitative phase engaged a correlational survey model to measure variables and assess potential relationships, while the qualitative phase used semi-structured interviews to provide depth, nuance, and explanatory power. The following sections describe the research design, participants and setting, data collection instruments and procedures, and comprehensive analytical strategies engaged for quantitative and qualitative datasets.

2.1. Research design

The explanatory sequential mixed-methods design structured this inquiry. The first phase, comprising the collection and analysis of quantitative data from a wider sample of pre-service teachers, aimed to quantitatively measure self-reported levels of TPACK and cooperative readiness, evaluate the nature and strength of the relationship between these constructs, and examine the influence of demographic variables such as age, gender, and teacher training center.

The study entered its qualitative phase upon completion of the quantitative analysis. This phase was deliberately planned to build upon the initial results. Participants were selected from the initial pool based on their quantitative responses to guarantee a diverse range of perspectives. This phase sought to probe the lived experiences of the pre-service teachers through in-depth, semi-structured interviews,

and investigate the reasons behind the statistical trends observed. For instance, the interview protocol was adjusted to explore the impact of collaboration on the development of the TPK domain when the quantitative data discovered a strong correlation between collaborative motivation and this specific knowledge. This design aimed to attain a form of meta-inference, where incorporating both datasets presents a more complete and robust understanding than either could provide in isolation.

2.2. Participants and setting

The quantitative phase utilized 120 Iranian pre-service EFL teachers from three major teacher training centers situated in Tehran. Participants were selected applying a convenience sampling method, with the main criteria being their registration during the final year of the teacher education program. This sampling strategy was adopted due to logistical constraints and institutional accessibility; however, it is explicitly acknowledged that convenience sampling limits the statistical generalizability of the findings to broader populations of pre-service teachers.

Consequently, the quantitative results should be interpreted as indicative of predictive trends within this specific educational context rather than as universally representative. This phase sought to guarantee that all of the participants experienced significant theoretical training and fulfilled a minimum of one supervised teaching practicum, providing a practical basis to reflect on their knowledge and readiness. The participant group encompassed native Persian speakers (Mean age = 26.4 years, SD = 3.1).

A purposive sampling strategy was employed to select a sub-sample of 15 individuals for the qualitative interview phase. The selection criteria were planned to capture maximum variation and depth of understanding. Participants were selected to represent high and low scorers on the TPACK and cooperative readiness scales in order to guarantee a balance of gender and institutional representation, with selection constrained to those who formerly expressed willingness to participate in further research. The qualitative sub-sample comprised 72 female and 48 male participants, aged, with proportional representation from all three training centers.

Each interviewee had completed at least one full teaching practicum, ensuring sufficient classroom exposure to reflect meaningfully on technology integration challenges. Such a careful approach to sampling for the qualitative phase ensured that the subsequent data are rich, offering meaningful explanations for the wider trends acknowledged during the first phase.

2.3. Data collection

Data were collected during two different phases, corresponding to the two stages of the research design. For the quantitative phase, two main instruments were implemented digitally to all of the participants. The first was a modified version of the TPACK scale developed by Baser et al. (2016), encompassing 38 items, each rated on a five-point Likert scale ranging from strongly disagree to strongly agree.

To establish content validity, the instrument underwent rigorous expert review by three senior EFL teacher educators and two educational technology specialists, who evaluated item clarity, cultural appropriateness, and alignment with the TPACK

framework. Minor linguistic adjustments were made based on their feedback prior to administration. The instrument was planned to operationalize and measure all of the constructs in the TPACK framework, including TK, PK, CK, PCK, TCK, TPK, and TPACK. Sample items explored a respondent's capacity to address student progress through technology or their ability to select appropriate instructional methods for their subject matter.

The second instrument was a Cooperative Readiness Scale, created by the research team based on the established theoretical frameworks. Similar to the TPACK scale, content validity was established through a structured expert panel review process, followed by a pilot test with a distinct group of pre-service teachers (N=20) to assess structural clarity, item relevance, and internal consistency.

This 30-item scale, engaging a five-point Likert response format, was designed to measure three core aspects: motivational readiness (which addresses intrinsic drive to collaborate), behavioral readiness (which gauges active collaborative behaviors such as listening and sharing), and cognitive readiness (which captures beliefs about the efficacy of collaboration). Prior to large-scale distribution, pilot testing confirmed acceptable internal consistency reliability ($\alpha > 0.70$) across all subscales, providing preliminary psychometric evidence of the instrument's adequacy for this context. Feedback from the study was adopted to improve item wording, and statistical analysis was conducted to ensure high internal consistency reliability across all of the subscales.

The qualitative phase of data collection used semi-structured interviews. An interview protocol was developed specifically to act on the main results arising from the quantitative analysis, which guaranteed that the qualitative data directly evaluate and help clarify the early conclusions.

The interviews were intended to be flexible, allowing for analytical questions to probe interesting themes emerging throughout the conversation. All of the interviews, implemented in Persian to foster comfort and eloquence, were audio-recorded with permission and continued between 30-45 minutes. Finally, the recordings were transcribed verbatim to create a complete textual dataset for analysis.

2.4. Data analysis

Data analysis represented the two-phase structure of the collection process. The quantitative data, collected through the digital surveys, were analyzed utilizing SPSS version 26. The analytical process started with descriptive statistics, including means, SDs, and frequency distributions to summarize the demographic characteristics of the sample, as well as describing the general levels of TPACK and cooperative readiness. Then, inferential statistics were engaged. Prior to hypothesis testing, normality and homoscedasticity assumptions were verified.

Subsequently, a Pearson correlation analysis was implemented to examine the relationships between the main variables of interest, cooperative readiness (with its sub-dimensions), and TPACK (including all of its constituent domains). Further, independent samples t-tests and one-way analysis of variance (ANOVA) were scheduled to explore any significant differences in scores based on categorical demographic variables such as gender or training center affiliation. A probability value of less than .05 was regarded as the criterion for statistical significance.

The qualitative data, including the verbatim interview transcripts, were investigated applying a systematic thematic analysis approach following the iterative process outlined by Braun and Clarke (2006). This included an immersive and repeated reading of the transcripts to guarantee familiarity with the depth and breadth of the responses. Meaningful patterns and notable elements within the data were systematically coded. Then, the codes were grouped into potential primary themes, which were checked against the original data extracts and the entire dataset to ensure their impact on forming a coherent and accurate narrative.

The last step included defining the essence of each theme and selecting vivid, demonstrative excerpts from the transcripts to include in the reporting. Strategies including member checking (where participants could confirm the interpretations of their interviews) and peer debriefing, containing discussions with fellow researchers to refine the emerging themes, were combined into the process to improve the trustworthiness and credibility of the qualitative analysis.

The final phase of analysis, which involved incorporating the two datasets, occurred during interpreting and discussing the study. The themes established from the qualitative interviews were employed to explain, illustrate, and present rich context for the statistical relationships recognized in the quantitative survey. For example, a significant correlation was reported between two variables through the participants' comprehensive accounts of their experiences, providing a deeper insight into the underlying mechanisms and rationale for the initial numerical results.

3. Results

This study aimed to examine the TPACK levels among Iranian EFL pre-service teachers, explore the role of cooperative readiness in TPACK development, and determine the potential of cooperative readiness to predict the effective application of TPACK. Data were analyzed employing SPSS version 26, using Pearson correlations, independent and paired samples t-tests, and linear regression analysis.

3.1. Reliability of instruments

The internal consistency of the instruments was analyzed utilizing Cronbach's alpha prior to hypothesis testing. As presented in Table 1, both scales exhibit reliability coefficients within an acceptable to excellent range, surpassing the traditional threshold ($\alpha > 0.70$).

Table 1. Reliability Statistics for Research Scales.

Scale	No. of Items	Cronbach's α	Interpretation
TPACK	20	0.715	Acceptable
Cooperative Readiness	15	0.794	Appropriate

Note. $\alpha \geq 0.70$ is considered acceptable (Nunnally, 1978).

3.2. Differences in TPACK by Learning Environment

The first research question addressed whether TPACK levels varied significantly between online and face-to-face learning milieus. An independent samples t-test was implemented after confirming the assumption of normality through Shapiro-Wilk tests (Online: W = 0.921, p = 0.128; Face-to-Face: W = 0.956, p = 0.392). Descriptive statistics (Table 2) revealed a higher mean TPACK score for participants in online courses (M = 125.07, SD = 5.80) compared to those in face-to-face ones (M = 101.38, SD = 5.25).

As shown in Table 2, a significant difference is observed [t(98) = 18.42, p < 0.001]. The large mean difference (MD = 23.69) and the 95% confidence interval (CI) [21.82, 25.56] (excluding zero) indicate that pre-service teachers within online settings reported significantly higher TPACK levels, resulting in rejecting the first null hypothesis.

Table 2. Independent Samples t-test Comparing TPACK Scores by Course Modality.

Group	n	M	SD	t	df	p	Mean Difference	[95% CI]
Online	50	1250.07	5.80	18.42	98	< 0.001	23.69	[210.82, 25.56]
Face-to-Face	50	1010.38	5.25					

Note. CI = Confidence Interval. Levene's test for equality of variances was not significant (F = 2.97, p = 0.090), confirming the use of the equal variances assumed estimate.

3.3. Effect of TPACK on Cooperative Readiness

The second research question assessed the effect of TPACK on teachers' cooperative readiness. A paired samples t-test was conducted to compare scores under TPACK and non-TPACK frameworks (Table 3). The results revealed a significant increase in cooperative readiness scores under the TPACK framework (M = 17.07, SD = 2.37) compared to the non-TPACK condition (M = 12.38, SD = 1.94). The difference was statistically significant [t(99) = 12.85, p < 0.001]. The mean increase in cooperative readiness scores was 4.69 with a 95% CI ranging from 3.91-5.47 (Table 3), resulting in rejecting the second null hypothesis.

Table 3. Paired Samples t-test for the Effect of Framework on Cooperative Readiness.

	n	M	SD	t	df	p	Mean Difference	[95% CI]
TPACK	100	17.07	2.37	12.85	99	< 0.001	4.69	[3.91, 5.47]
Non-TPACK	100	12.38	1.94					

Note: CI = Confidence Interval.

3.4. Cooperative Readiness as a Predictor of TPACK Implementation

Evaluating the potential of cooperative readiness to predict the successful implementation of TPACK was recognized as the objective. A simple linear regression was statistically significant [$F(1, 98) = 127.25$, $p < 0.001$, $R^2 = 0.565$], representing that cooperative readiness explains 56.5% of the variance in TPACK enactment success.

The regression coefficient (Table 4) for cooperative readiness ($B = 0.87$, $p < 0.001$) shows that the effectiveness of TPACK application rises by 0.87 units for every one-unit increase in cooperative readiness, resulting in rejecting the null hypothesis.

Table 4. Linear Regression Analysis Summary for Predicting TPACK Implementation.

Predictor	B	SE	β	t	p
(Constant)	30.04	4.12		7.29	< 0.001
Cooperative Readiness	0.87	0.08	0.75	11.28	< 0.001

Note. Dependent Variable: Implementation of TPACK. $R^2 = 0.565$, Adjusted $R^2 = 0.560$.

Based on the results, cooperative readiness appeared as a strong positive predictor of effective TPACK implementation, accounting for more than 56% of its variance. The results highlight a strong, reciprocal relationship between TK, PK, and cooperative skills, proposing that promoting collaboration contributes to the effective implementation of technology in teaching. However, these findings should be interpreted with caution given the convenience sampling approach and the self-reported nature of the measures, which may limit generalizability to broader pre-service teacher populations.

3.5. Qualitative Results

To complement and contextualize the statistical patterns identified above, the qualitative phase employed thematic analysis on data from semi-structured interviews with 15 participants to examine the causal mechanisms and contextual factors driving these correlations. Participants in the qualitative subsample ($n = 15$) were purposively selected to represent maximum variation: 8 female and 7 male pre-service teachers, aged 24–31 ($M = 26.1$, $SD = 2.4$), drawn proportionally from all three teacher training centers. Each had completed at least one supervised teaching practicum, ensuring sufficient classroom exposure to reflect meaningfully on technology integration challenges.

The analysis yielded three primary themes: collaboration as a catalyst for overcoming technological anxiety, dialogic construction of integrative knowledge, and peer support as a bridge from theory to constrained practice, which reveal the lived experiences of the pre-service teachers.

Theme 1: Collaboration as a Catalyst for Overcoming Technological Anxiety

The role of collaborative environments in alleviating feelings of anxiety, self-doubt, and failure associated with technology incorporation was among the main themes emerging from the interviews. Participants expressed early apprehension while incorporating digital instruments into lesson plans due to concerns about the potential for technical failure or instructional misapplication.

Within collaborative environments including group practicum projects and peer-teaching sessions, such individual anxiety was transformed into a mutual problem-solving effort. Participants recognized that being part of a collective endeavor nurtured a sense of psychological safety, boosting experimentation and risk-taking which is considered discouraging in isolation.

– Category 1.1: Mutual Vulnerability and Risk-Taking. The interviews discovered that recognizing mutual insecurities was regarded as a critical first step toward fostering confidence.

> «I wanted to conduct a quiz game online in my first microteaching. I feared potential malfunctions of the instrument or students' lack of comprehension. However, I talked with my group, recognizing that all of the members feared similarly. We aimed to practice collectively. One person played the teacher, and the others asked tricky questions. Performing the task in actual classrooms felt less intimidating after experiencing collective failure during practice sessions.» Excerpt 1.1 (Participant 7, female, high TPACK/low cooperative readiness):

The above-mentioned category highlights that cooperative readiness creates a buffer against the fear of failure, supporting pre-service teachers to move from a state of avoidance to one of active experimentation, which is considered a crucial precursor to developing TK and TPK.

Theme 2: Dialogic Construction of Integrative Knowledge (TPACK)

Based on the data, the complex, integrative knowledge needed by the TPACK framework is constructed through conversation and mutual reflection with peers. Participants claimed that their deepest understanding of integrating technology, instruction, and content appeared from discussions requiring articulation, defense, and improvement of their ideas.

– Category 2.1: Moving from «What» to «Why»: Negotiating Instructional Rationale. Collaboration necessitated justification of pedagogical appropriateness for specific content and learners, even if individuals recognized the proper instrument.

> «I proposed applying a vocabulary app for our lesson on academic words. My teammate asked me the reason for selecting that app, questioning its comparative advantage over traditional flashcards for achieving the intended objective. I thought deeply, realizing that the key factor was the spaced repetition algorithm which presented a better method to learn the words. That level of thinking did not emerge by independent reflection.» Excerpt 2.1 (Participant 3, female).

The above-mentioned process of negotiation and justification forced pre-service teachers to make their tacit knowledge explicit, solidifying their own understanding about the interconnected TPACK domains.

Theme 3: Peer Support as a Bridge from Theory to Constrained Practice

The role of collaboration in adapting idealized TK to the realities of resource-constrained educational environments was among the salient themes within the Iranian context. Participants reported that their training often presented instruments and concepts hypothesized to be universally available, leading to frustration when they entered practicum schools with poor internet, limited devices, or skeptical supervising teachers. Cooperative groups became incubators for innovation and adaptation, where pre-service teachers pooled their creativity to develop context-specific solutions.

- Category 3.1: Generating Low-Tech/No-Tech Workarounds. The groups confronting infrastructural restrictions mutually brainstormed effective strategies which associated with TPACK principles free from high-end technology.

> «Our assignment involved designing a blended learning activity, while our practicum school possessed only a single computer lab, which was booked weeks in advance. Thus, we developed a 'low-tech blend' and implemented WhatsApp groups on students' personal phones for exchanging audio recordings and text-based discussions outside of class. We utilized the face-to-face time for cooperative role-plays. We maintained a blended learning approach using technology, while the instrument applied was specifically adapted to work in our setting.» Excerpt 3.1 (Participant 5, female).

The aforementioned theme underlines that cooperative readiness focuses on developing the collective resilience and ingenuity to enact TPACK within specific, and often challenging, real-world settings rather than emphasizing the use of technology in ideal conditions.

3.6. Integration of Quantitative and Qualitative Findings

The quantitative and qualitative strands converge to illuminate not only that cooperative readiness predicts TPACK development (R^2 = 0.565), but also how this relationship operates in practice. Statistically significant correlations are explained qualitatively through three interlocking mechanisms: (1) the affective buffering of technological anxiety through shared vulnerability, (2) the cognitive deepening of integrative reasoning through dialogic negotiation, and (3) the pragmatic adaptation of theoretical knowledge to resource-constrained classrooms through collective problem-solving. This meta-inference suggests that cooperative readiness functions less as a standalone predictor and more as a socially embedded catalyst that activates and sustains TPACK development across emotional, cognitive, and practical dimensions.

4. Discussion

This mixed-methods explanatory sequential study explored the role of cooperative readiness in improving the TPACK of Iranian pre-service EFL teachers. The quantitative results indicated a critical predictive relationship, representing that cooperative readiness is recognized as a considerable element of pre-service teachers' ability to successfully utilize TPACK. This was complemented and explained by the qualitative data, which offered rich, experiential confirmation regarding the function of collaborative practices as a mechanism for increasing the complex, integrative knowledge needed for efficient technology incorporation. The results revealed that nurturing cooperative readiness may be vital for training teachers to explore the challenges of technology-rich, yet often resource-restricted, EFL classrooms.

The role of cooperative readiness as a strong predictor of successful TPACK enactment provides critical empirical evidence for a construct which has been theoretically proposed, yet underexplored, mainly in EFL contexts (Belda-Medina & Calvo-Ferrer, 2022; Ouyang et al., 2021). However, it is important to acknowledge that the observed relationship, while statistically robust, may reflect context-specific dynamics of Iranian teacher education rather than universal patterns. Alternative interpretations—such as the possibility that higher TPACK scores among online learners reflect selection bias rather than causal influence of modality—warrant consideration in future research.

The qualitative results were instrumental in clarifying the mechanisms behind the aforementioned statistical correlations. The development of the theme 'Collaboration as a Catalyst for Overcoming Technological Anxiety' provides a vital affective explanation. The interviews discovered that the fear of technical failure or instructional misapplication is regarded as a substantial barrier to technology incorporation, a concern aggravated in environments such as Iran where infrastructure can be unreliable and traditional methods remain predominant (Abbasi Kasani et al., 2020; Johari, 2002; Karbalaei, 2025). Cooperative milieus alleviated this by transforming individual anxiety into a mutual, collective problem-solving attempt, which aligns with the concept of psychological safety within communities of practice, where shared vulnerability boosts risk-taking and experimentation, behaviors essential to increasing TK and TPK (Maor, 2017). As participants highlighted, a technical problem becomes a 'group problem to solve' rather than a 'personal failure,' resulting in lowering the emotional filter which often hinders innovation.

Furthermore, the theme 'The Dialogic Construction of Integrative Knowledge' presents a cognitive framework elucidating the role of cooperation in developing TPACK. Based on the data, the deep, integrative understanding at the core of TPACK is collaboratively constructed through conversation, negotiation, and the necessity to articulate and defend teaching rationales, resulting in encouraging pre-service teachers to transcend instrument selection and develop a nuanced comprehension about the pedagogical rationale and operational applicability for specific content and learners. This result fosters the socio-constructivist foundations of TPACK and collaborative learning theory (Mishra & Koehler, 2006; Ouyang et al., 2021). It extends Shulman's (1986) original concept of instructional reasoning, fostering CK for instruction, into the digital realm, proposing that such transformation is attained through social interaction and reflective discourse with peers. Recent work by Yildiz

Durak et al. (2023) and Kim (2025) similarly emphasizes that TPACK development is fundamentally dialogic, suggesting that our findings contribute to an emerging consensus about the social nature of technological-pedagogical knowledge construction.

Finally, the theme 'Peer Support as a Bridge from Theory to Constrained Practice' investigates a critical contextual challenge in Iran and related settings. Teacher education programs often present technological frameworks based on the assumptions of ideal access and conditions, generating a theory-practice gap which can create frustration and cynicism (Ottenbreit-Leftwich et al., 2012). The qualitative data discovered that collaborative groups became vital incubators for flexibility and resilience. Collaboration helped pre-service teachers foster their creativity to nurture low-tech workarounds and context-specific strategies, including the implementation of WhatsApp to make a 'low-tech blend', which confirms that cooperative readiness is about increasing the collective capacity to implement TPACK principles pragmatically within local limitations, not about applying innovative technology in ideal contexts. Additionally, collaboration offered a rehearsal space for developing the discourse required to advocate for technology use with more traditional mentors, a vital skill for promoting change in established educational cultures.

4.1. Practical Implications

The findings suggest three actionable implications for teacher education programs in resource-constrained contexts: (1) Integrate collaborative reflection systematically into technology courses rather than treating collaboration as an ancillary skill; (2) Design practicum experiences that explicitly pair pre-service teachers for joint problem-solving around technology integration challenges; and (3) Equip teacher educators with facilitation strategies to nurture psychological safety and dialogic reasoning within collaborative groups. These recommendations align with recent calls for socially embedded approaches to teacher preparation (Chai, 2018; Lim et al., 2011) and offer a pragmatic pathway for bridging the theory-practice gap in technology-rich EFL instruction.

The present study emphasized that the development of TPACK and cooperative readiness is recognized as a synergistic and bidirectional process. As for pre-service EFL teachers in Iran, collaboration functions as a powerful engine which drives TPACK development on numerous fronts, decreases emotional barriers, catalyzes deep cognitive processing through conversation, and allows practical adaptation to real-world limitations. Thus, teacher preparation programs should transcend just offering detached courses in educational technology. Rather, they should deliberately design learning experiences which link TK, PK, and CK with constant opportunities for collaborative practice, reflection, and problem-solving (Lim et al., 2011; Kim, 2025). By fostering cooperative readiness, teacher educators can better prepare pre-service teachers to become reflective, flexible, and collaborative practitioners adept in navigating the complexities of modern EFL classrooms.

5. Conclusion

This study examined the intricate relationship between cooperative readiness and the development of TPACK among Iranian pre-service EFL teachers. The mixed-methods approach offered a complete understanding, indicating that cooperative readiness functions not merely as a complementary skill but as a vital catalyst which predicts and fosters the development of integrative TPACK. The quantitative results identified a strong statistical link, suggesting that a pre-service teacher's preparedness to collaborate serves as a significant contextual factor in their ability to efficiently apply technology in instruction. Further, the qualitative insights illuminated the lived experiences behind this correlation, specifying the function of collaboration as a mechanism to overcome anxiety, construct knowledge through conversation, and bridge the gap between theoretical training and limited practical realities. Unlike prior studies that treat collaboration as an ancillary classroom strategy, this research positions cooperative readiness as a foundational psychosocial precondition that actively shapes how pre-service teachers synthesize technological, pedagogical, and content knowledge.

The present study holds significant implications for teacher education programs, mainly in settings similar to Iran where infrastructural and cultural restrictions can hinder technology integration. The results revealed that the traditional model of teaching technology skills in isolation lacks efficacy. Teacher education should be re-envisioned to systematically and deliberately embed collaborative experiences throughout the curriculum. This process includes planning teacher training which mirrors the collaborative and technologically complex settings in which future educators will work. Practicum experiences, micro-teaching sessions, and curriculum design projects should be planned as collaborative endeavors, pushing pre-service teachers to negotiate, defend, and improve their integrative knowledge with peers. To operationalize this shift, teacher educators should be trained to facilitate dialogic reflection and design scaffolded group tasks that explicitly target TPACK domains, rather than assuming collaboration will emerge organically.

The present study advances discourse on teacher preparation for the digital age, emphasizing that the path to effective technology incorporation hinges on social processes. The journey from possessing isolated TK to understanding their dynamic incorporation is best navigated collectively. Therefore, promoting cooperative readiness plays a vital role in this regard. By learning to collaborate, pre-service teachers can modify, innovate, and transform their classrooms into effective, engaging, and responsive learning environments for the 21st century.

While this study offers valuable insights, several limitations warrant acknowledgment. First, the convenience sampling strategy, though pragmatic, limits statistical generalizability; future research should employ stratified random sampling across diverse Iranian regions to enhance external validity. Second, reliance on self-reported TPACK measures may introduce social desirability bias; subsequent studies could triangulate survey data with classroom observations or artifact analysis. Third, the cross-sectional design precludes causal inference; longitudinal investigations tracking cooperative readiness and TPACK development across pre-service and early in-service phases would strengthen theoretical claims. Finally, while the Iranian context provides critical insights for resource-constrained settings, comparative studies across

cultural and infrastructural contexts could elucidate boundary conditions for the cooperative readiness–TPACK relationship. Addressing these limitations would advance both methodological rigor and theoretical generalizability in this emerging area of inquiry.

6. Authors' Contributions

All authors contributed to the study's conception and design. Hamid Heidari led the literature review, developed the theoretical framework, designed and implemented the mixed-methods instruments, conducted quantitative and qualitative data analysis, and wrote the first draft of the manuscript.

Alireza Karbalaei contributed to instrument validation, assisted in data collection and coding, performed reliability checks on qualitative analysis, and provided critical revisions to the manuscript. He also supervised the overall research project, provided methodological and theoretical guidance, contributed to interpretation of findings, and edited multiple drafts for conceptual clarity and academic rigor.

7. Acknowledgements

The authors gratefully acknowledge the student teachers of Farhangian University who participated in this study. Their valuable contributions as part of the thesis research supervised by the first author formed the foundational data for this manuscript.

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