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Integration of Digital Technology in EFL Instruction: A Comparative Study of TPACK Development among Pre-service and In-service Teachers*

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ABSTRACT

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This study examines the Technological Pedagogical Content Knowledge (TPACK) of pre-service and in-service English as a Foreign Language (EFL) teachers using a validated TPACK-EFL questionnaire (Baser et al. 2016). Based on an in-depth analysis of quantitative data such as descriptive statistics, correlation analysis, MANOVA, and ANOVA, this study provided a comprehensive understanding of TPACK development across the two groups. The findings revealed that both groups demonstrated moderate levels of TPACK, although in-service teachers scored significantly higher across all TPACK domains. The results further highlighted distinct patterns in TPACK development: pre-service teachers were more strongly influenced by technology-related knowledge domains, whereas in-service teachers placed greater emphasis on content-related knowledge. These differences suggest the need for differentiated approaches in teacher education and professional development programs to support effective technology integration and content delivery. The findings also support the validity of the self-report measure for assessing TPACK and highlight important differences in the developmental trajectories of pre-service and in-service teachers. Overall, the study underscores the need to strengthen teacher education curricula by fostering a more effective integration of technological and content knowledge, which contributes to the growing body of research on TPACK in an era of increasing educational digitalization.

KEYWORDS

technological pedagogical content knowledge (TPACK), teacher education, English as a Foreign Language, in-service teacher, pre-service teacher

1. Introduction

As we enter a new phase of the digital era, the development and application of Technological Pedagogical Content Knowledge (TPACK hereafter) has become important for educators worldwide (Chai et al. 2011). This global trend is no exception in China, where the role of digital technology in education has been underscored by a wave of policy initiatives. The Chinese government has invested considerable effort in the development of TPACK among teachers, viewing it as a mandatory criterion for effective teaching in the age of educational informatization (Wu 2014). In May 2014, The Standard of Primary and Secondary School Teachers' Information Technology Application Ability (Trial Implementation) issued by the Ministry of Education of the People's Republic of China pointed out that the ability to apply digital technology is a necessary professional ability for teachers. It also put forward the technological requirements to optimize classroom environments and to change the learning mode of students (Ministry of Education of the People's Republic of China 2014). In 2018, Education Informatization 2.0 Action Plan issued by the Ministry of Education of China stated that to improve teachers' TPACK, it is necessary to strengthen the training of teachers' digital literacy and technology-enhanced teaching ability (Ministry of Education of the People's Republic of China 2018). Therefore, the policies issued by the Chinese government aim to equip both pre-service teachers (PETs hereafter) and in-service teachers (IETs hereafter) with the necessary competencies to navigate the emerging complexities of the digitized classroom effectively. However, the transition towards a technology-integrated pedagogical landscape faces many challenges. Within the Chinese context, several studies have pointed out the inadequacy in the level of TPACK especially for PETs (Dong et al. 2014, Wang and Fu 2015). One of the contributing factors to this issue is the existing structure of teacher training programs, where professional English courses and teacher education courses are administered separately (Xiang 2018). This approach leads to the acquisition of knowledge and skills that are not integrated or customized to cater to specific teaching contexts or the integration of technology into subject teaching. Additionally, the lack of alignment between theoretical learning and practical application further compounds these issues (Xiang 2018). With this in mind, the current study aims to diagnose the current state of TPACK among EFL (English as a Foreign Language) teachers in China, comparing specifically two groups of EFL teachers: PETs and IETs.

While previous studies have noted the limited number of comparative investigations between pre-service and in-service EFL teachers, the importance of such comparisons lies not merely in addressing a research gap but in understanding how teacher knowledge develops across different stages of professional experience. Comparative approaches have been widely recognized as essential for identifying differences in knowledge construction, instructional beliefs, and technology integration practices between novice and experienced teachers (e.g., Dong et al. 2015). In the context of TPACK, these comparisons are particularly important because teacher knowledge is not static but shaped by both formal teacher education and classroom experience. Without comparative analysis, it is difficult to determine whether observed limitations in TPACK stem from deficiencies in pre-service preparation, constraints in in-service environments, or the interaction between the two.

Although this study is situated within the Chinese educational context, the findings are expected to offer meaningful implications for broader EFL settings. China represents a large-scale, policy-driven model of digital integration in education, where both PET and IET development are systematically emphasized. As many EFL contexts worldwide face similar challenges in aligning technological, pedagogical, and content knowledge, the patterns identified in this study may provide insights into how institutional structures, teacher education programs, and policy initiatives shape TPACK development. The research questions that guide this study are as follow:

1. What are the current levels and characteristics of TPACK among pre-service and in-service EFL teachers?
2. How do TPACK components relate to one another within each group, and what differences exist between PETs and IETs across TPACK constructs?

2. Literature Review

2.1 The Definition of TPACK

TPACK refers to teachers' ability to effectively teach specific subject matter using appropriate pedagogical approaches and technological tools. It emphasizes the dynamic interaction among content, pedagogy, and technology, requiring teachers to make context-sensitive decisions about how to represent subject matter, design learning activities, and use technology to enhance student understanding (Mishra and Koehler 2006). As shown in Figure 1, the TPACK framework comprises three core components: technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK). The interaction of these three forms of knowledge gives rise to pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and TPACK (Koehler and Mishra 2009). In addition, context is an essential component of TPACK that influences the way the other components interact and function (Koehler and Mishra 2009).

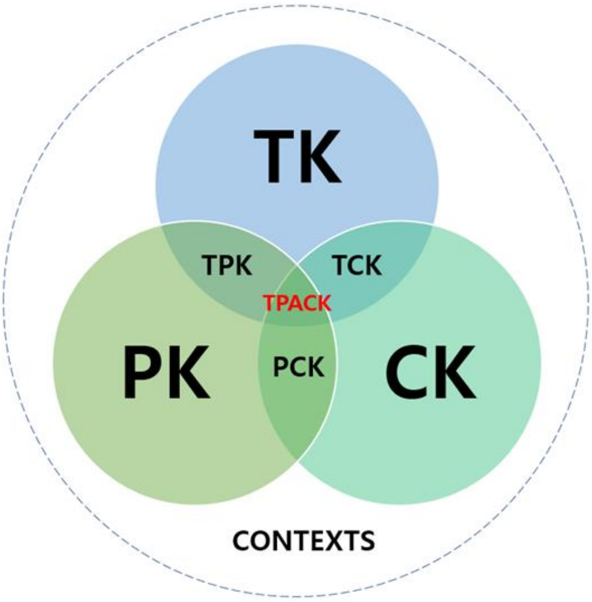

Figure 1. TPACK Framework (adapted from Koehler and Mishra 2009)

The TPACK component requires an understanding of the intricate relationships between TK, PK, and CK, involving the skillful integration and dynamic balancing of these elements (Mishra and Koehler 2006). TK in TPACK refers to understanding and working with various technology tools and resources. TK also encompasses knowledge of operating systems, computer hardware, standard software tools, and the ability to adapt to new technologies (Mishra and Koehler 2006). CK in the TPACK framework pertains to a teacher's understanding of the subject matter to be taught. It includes a deep comprehension of ideas, concepts, theories, organization frameworks, proof and evidence, as well as traditional teaching practices and methods. PK is a teacher's profound understanding of teaching and learning processes and practices. It encompasses educational purposes, values, and aims. PK involves knowledge of effective methods and approaches to teaching specific topics, as well as scaffolding concepts for learners with diverse abilities and interests. It emphasizes engaging students in higher order activities, using authentic examples, and accommodating different learning styles (Koehler and Mishra 2009). Furthermore, the intersections of these components (PCK, TCK, and TPK) involve a complex synthesis of the foundational elements of TPACK, which helps teachers effectively integrate technology into their pedagogy (Koehler and Mishra 2009). Specifically, PCK is the combination of a teacher's CK and PK, which refers to teachers' ability to transform subject matter into forms that are comprehensible and teachable to learners, by selecting, organizing, and representing content in ways that align with students' prior knowledge, misconceptions, and learning needs (Shulman 1987). TCK is the understanding of how technology and CK impact each other. Teachers with TCK choose appropriate technology to make content more accessible to learners. TPK integrates TK with PK., which refers to an understanding of how teaching and learning can change when particular technologies are used, and how to select and use technological tools to support pedagogical strategies across different instructional contexts (Mishra and Koehler 2006).

2.2 TPACK in Teacher Education in EFL Context

The TPACK framework is vital for teacher training in the current digital era (Chai et al. 2011, Koehler et al. 2007). As a theoretical foundation for integrating technology into teaching, the TPACK framework specifies the required knowledge for teaching with technology (Willermark 2018) and offers a theoretical lens for teachers to consider teaching methods and how to achieve student-centered learning (Guzey and Roehrig 2009, Schmidt et al. 2009). In this regard, Koh et al. (2017) revealed that the TPACK framework was essential for shaping teachers' attitudes toward using technology in teaching and making the integration of technology accessible and more effective in classrooms.

In the context of EFL education, technology integration, supported by an understanding of TPACK, is transforming traditional teaching methods and approaches. For example, computer assisted language learning (CALL) has expanded possibilities for interactive language practice, multimedia materials, and personalized learning (Levy and Stockwell 2006). Mobile assisted language learning (MALL) has enabled ubiquitous and context-rich language learning opportunities (Kukulska-Hulme 2012). Immersive technologies such as virtual reality (VR), augmented reality (AR) technology are also being explored to create immersive and experiential language learning experiences (Lee and Park 2019, Lee and Hwang 2022, Jeon et al. 2022, Merchant et al. 2014). More recently, Gen AI technology has dramatically changed the educational landscape by providing customized learning opportunities (see Lo et al. 2024 for a systematic review). Likewise, a large number of studies have revealed that incorporating digital technology in EFL classrooms can increase learner engagement, motivation, and autonomy, leading to improved language proficiency (Azmi 2017, Kukulska-Hulme 2012, Levy and Stockwell 2006).

The rapid advancement of technology requires EFL teachers to adapt their instructional practices to meet the needs and expectations of digital native learners. Su (2023) has shown that EFL teachers with higher TPACK levels are more likely to use technology effectively in their classrooms. This is because TPACK provides teachers with the ability to select appropriate technology tools, design engaging learning activities, and effectively assess student progress (Mishra and Koehler 2006). This holistic understanding of technology integration empowers pre-service EFL teachers to create engaging and meaningful learning experiences.

However, many traditional teacher education programs struggle to adequately address the effective integration of technology in EFL instruction. This is primarily attributed to the lack of experiences and knowledge of how to effectively incorporate technology into their language teaching practices (Aydin 2013). In this regard, pre-service EFL teachers' TPACK development is crucial for effective technology integration in instruction, and this can be enhanced through pedagogical coursework, hands on experiences with technology tools, collaborative learning opportunities, and reflective practices (Rahimi and Pourshahbaz 2019). In addition, it is important to assess the existing TPACK competency level of in-service EFL teachers. Following this assessment, the development and application of pedagogical strategies should be aligned with these identified TPACK competencies to ensure effective and targeted educational advancement (Koehler and Mishra 2009, Su 2023).

Although a growing body of research has examined TPACK in teacher education, the findings remain inconsistent, particularly in relation to differences between PETs and IETs. Some studies suggest that IETs demonstrate higher overall TPACK due to accumulated classroom experience and opportunities to integrate content, pedagogy, and technology in practice (e.g., Dong et al. 2015, Tondeur et al. 2020). In contrast, other studies report that PETs exhibit relatively stronger technological knowledge, reflecting their greater exposure to digital tools during their university training (Chai et al. 2011). These mixed findings point to a lack of consensus regarding how TPACK develops across different stages of teacher education. While some researchers implicitly assume a linear progression from pre-service to in-service stages, others argue that TPACK development is not uniform across its components, but varies depending on contextual factors such as institutional support, access to technology, and opportunities for authentic teaching practice (Tondeur et al. 2020).

In particular, the relationship between technology-related constructs (e.g., TK, TPK) and content-related constructs (e.g., CK, PCK) remains underexplored in comparative studies. Existing research has largely focused on overall TPACK scores or general differences between groups, without examining how specific components of TPACK are differently emphasized or structured across PETs and IETs. As a result, it is still unclear whether observed differences reflect developmental progression, contextual constraints, or different emphases across TPACK constructs. Furthermore, in EFL contexts, where the integration of technology is often shaped by curriculum demands and language-specific pedagogical considerations, these inconsistencies may be even more pronounced. However, relatively few studies have systematically examined how TPACK components interact within EFL teacher preparation and practice, particularly in large-scale comparative designs.

The current study aims to address these gaps by moving beyond overall comparisons of TPACK levels and instead examining how different TPACK constructs are distributed and emphasized between pre-service and in-service EFL teachers. By doing so, this study seeks to contribute to ongoing debates on whether TPACK development should be understood as a linear progression or as a context-dependent and uneven process across knowledge domains.

3. Methods

3.1 Participants

To examine and compare the current situations of PET and IET's TPACK, participants were chosen from six universities and ten primary and secondary schools in Hebei Province, China. Given that the two groups represent distinct populations rather than a longitudinal cohort, the comparison in this study is not intended to trace developmental progression but to examine differences and similarities across stages of teacher preparation and practice.

For the selection of PETs, the researchers employed cluster sampling, a commonly used probability sampling technique for studying large populations. This approach aimed to capture a varied representation of PETs from different institutions and geographical locations within the province. These institutions were chosen based on their recognized English Language Teacher Education Programs and their contribution to the overall pool of potential PETs in Hebei Province. Within each institution, juniors and seniors enrolled in the programs were included. Almost all these PETs had completed basic specialized courses and related English language education and teaching methodology courses. A total of 1,436 questionnaires were collected from these institutions. After excluding those with a short response time and missing answers, 1,357 valid questionnaires remained, yielding a 94.5% valid response rate. The participant pool included 199 males (14.7%) and 1,158 females (85.3%). This significant gender gap is common in English language teacher education programs at Chinese universities.

In selecting the IETs, snowball sampling was used. A total of 301 valid questionnaires were collected from 10 primary and secondary schools in urban and rural areas of four cities in Hebei Province. Most participants were female (83.4%), reflecting the gender imbalance in the teaching profession in China, especially in language related subjects which are traditionally thought to be taught by female teachers. The ages of these participants ranged from 24 to 50 years, with the majority having more than 20 years of teaching experience (52.2%). Furthermore, 82.4% of the participants held a bachelor’s degree, followed by a master’s degree (9.3%) and a college degree (8.3%). All participants provided informed consent prior to participation. They were fully informed about the study’s purpose, procedures, potential risks, and benefits, and their right to withdraw at any time without consequence.

3.2 Data Collection

Drawing on the proposal of the TPACK framework by Mishra and Koehler (2006), various assessment methods and instruments have been employed to gauge its deployment among teachers such as self-report measures, open ended questionnaires, performance assessments, interviews, observations (Aktaş and Özmen 2022, Gill and Dalgarno 2017, Koh and Divaharan 2011, Mouza and Karchmer-Klein 2013, Pamuk 2012, So and Kim 2009, Tondeur et al. 2020,). Among various assessments and measures, this study adopts the self-report measure, which has become a favored method, requesting respondents to rate their self-perception of the various TPACK knowledge domains. In the current study, the TPACK survey developed and validated by Baser et al. (2016) was used. They developed and validated the TPACK self-assessment survey tailored for EFL teachers to comprehensively assess their technological, pedagogical, and content knowledge. The survey consists of several key items designed to evaluate the instructors’ proficiency and comfort in integrating technology into their teaching practices. These items are categorized into seven main domains: CK, PK, TK, PCK, TCK, TPK, and TPACK.

To date, a number of studies have examined teachers’ technological acceptance and development based on Baser et al. (2016)’ TPACK questionnaire (Budianto et al. 2023, Bustamante 2020, Gràcia et al. 2020, Luo and Zou 2023, Nazari and Xodabande 2022, Zhang and Chen 2022). The reasons for choosing the TPACK-EFL survey in this study are as follows: First, this survey is specifically designed to assess the TPACK development of EFL teachers. Second, it consists of seven sub-dimensions consistent with the seven constructs of the TPACK framework, enabling researchers to gain a comprehensive understanding of the current situations of the participants’ TPACK development. This survey comprises 39 items, and five point Likert type scale was used for all these items, in which the answers ranged from 1 (strongly disagree), 2 (disagree), 3 (neutral), 4 (agree), to 5 (strongly agree). The questionnaire also included items addressing demographic information of PETs and IETs, respectively (See Appendix for the questionnaire).

To conduct the survey, the researcher (i.e., the first author) began distributing the questionnaires to PETs and IETs. The data collection process lasted around one week. To help participants better understand the survey, it was translated into Chinese. The online Chinese version questionnaires were delivered to participants via official college emails and social network platforms such as QQ and WeChat to ensure maximum reach. All participants in training provided their informed consent before participating in the survey. An informed consent form was distributed to each participant, explaining the study's purpose and guaranteeing their anonymity and confidentiality. A number of reminders were disseminated to the participants, rewards were used as an incentive to fill out the survey and its all-inclusive nature sparked a higher willingness among them to participate. The questionnaire took approximately 10 minutes to complete.

Cronbach's Alpha reliability coefficients were used to test the internal consistency within each construct and the reliability of the scale. Cronbach's α was .933 for the TK construct, .936 for the CK construct, .957 for the PK construct, .953 for the PCK construct, .861 for the TCK construct, .961 for the TPK construct, .933 for the TPACK construct, and .968 for the whole scale. These values, all of which are above 0.7, indicate the acceptable reliability of the scale (Nunnally 1994).

3.3 Data Analysis

The quantitative analysis involved using SPSS 26.0 to analyze the collected numeric data through descriptive statistics, multivariate analysis of variance (MANOVA), and correlation analysis based on the research questions. For descriptive analysis, the mean and SD were calculated for the two groups. For MANOVA, the effect size (eta squared) was also used to validate the magnitude of the differences. Correlation analysis, specifically using Pearson's correlation coefficient, was employed to identify and measure the strength of relationships between TPACK and the six related constructs (TPK, TK, TCK, PK, PCK, CK). It is important to note that the TPACK framework represents a theoretically interdependent system in which constructs such as TK, PK, and CK interact to form combined constructs (e.g., TCK, TPK, PCK), which in turn contribute to TPACK. Therefore, correlation analysis was conducted as exploratory analyses to examine the relationships among TPACK components and to identify potential patterns in how different knowledge domains are associated with overall TPACK.

In this study, although the number of PETs was larger than that of IETs (approximately 4.51:1), unequal sample sizes alone do not necessarily threaten the robustness of parametric analyses unless accompanied by substantial heterogeneity of variance. Therefore, the assumption of homogeneity of variance was examined using Levene's test. In addition, the descriptive statistics showed relatively comparable standard deviations across the two groups, suggesting no substantial heterogeneity of variance between PETs and IETs.

4. Results

4.1 Pre-service and In-service EFL Teachers' TPACK

4.1.1 Pre-service teachers' TPACK

Table 1 presents the descriptive statistics for PETs. The mean scores of the seven constructs ranged from 3.49

to 3.69, indicating moderate levels of TPACK based on a five-point Likert scale. The highest value was observed for the PCK construct (M = 3.69, SD = 0.809), which suggests that PETs felt relatively more confident in their ability to teach subject matter content. In contrast, the TCK construct showed the lowest mean score (M = 3.55, SD = 0.813), indicating comparatively lower confidence in integrating technological tools with content knowledge.

Although all constructs are within a similar range, the difference between TK (M = 3.49, SD = 0.793) and PK (M = 3.66, SD = 0.827) suggests a relative imbalance between technology-related and pedagogy-related knowledge. One possible explanation is that PETs develop pedagogical knowledge primarily through coursework, while opportunities to apply technological tools in authentic content teaching remain limited. Therefore, rather than indicating low levels of TPACK, these findings suggest that PETs possess moderate overall competence with relatively weaker integration of technology and content knowledge. This pattern highlights the need for more targeted training that supports the practical integration of technology into English subject teaching.

Table 1. Descriptive Statistics for Pre-service EFL Teachers

Constructs	*N*	*M*	*SD*	*SE*	*Skewness*	*Kurtosis*
TK	1,357	3.49	0.793	0.022	-0.651	1.039
CK	1,357	3.57	0.814	0.022	-0.691	1.221
PK	1,357	3.66	0.827	0.022	-0.846	1.327
PCK	1,357	3.69	0.809	0.022	-0.743	1.275
TCK	1,357	3.55	0.813	0.022	-0.441	0.748
TPK	1,357	3.64	0.806	0.022	-0.803	1.366
TPACK	1,357	3.65	0.814	0.022	-0.723	1.190

Pearson's correlation coefficient was used to measure the relationships between the constructs. As Table 2 shows, statistically significant positive correlations existed among the constructs, with Pearson's r values ranging from 0.438 to 0.601. Interestingly, PK, PCK, TCK, and TPK maintained relatively stronger correlations with TPACK, particularly the correlation between TPK and TPACK.

Table 2. Correlation Analysis for Pre-service EFL Teachers

Constructs	TK	CK	PK	PCK	TCK	TPK	TPACK
TK	1						
CK	.438***	1					
PK	.474***	.545***	1				
PCK	.476***	.505***	.565***	1			
TCK	.467***	.518***	.459***	.490***	1		
TPK	.463***	.459***	.570***	.601***	.546***	1	
TPACK	.479***	.452***	.510***	.498***	.504***	.570***	1

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Overall, the correlation analysis suggests that the TPACK-related constructs were moderately and positively associated with one another within the PET group. In particular, the relatively strong relationships among TPK, PCK, and TPACK may indicate that PETs tend to connect technology use more closely with pedagogical processes than with authentic content integration. These findings provide further support for the need to strengthen opportunities for technology-integrated teaching practice within pre-service teacher education programs.

4.1.2 In-service EFL teachers' TPACK

As seen in Table 3, descriptive statistical analysis revealed mean scores of the seven constructs ranging between

3.80 and 3.93. IETs showed greater confidence in using technological tools to teach subject matter content knowledge and manage learning environments but less certainty in mastering technology knowledge. The analysis showed that IETs have a good command of some technological tools primarily used for teaching but struggle with solving common computer problems, indicating insufficient technology knowledge. These results underscore the need for TPACK training to focus on using subject-specific teaching technological tools and cover fundamental technology knowledge, as well as how to apply technology to support content and pedagogical knowledge.

Table 3. Descriptive Statistics for In-service EFL Teachers

Constructs	N	*M*	*SD*	*SE*	*Skewness*	*Kurtosis*
TK	301	3.80	0.831	0.048	-0.750	0.698
CK	301	3.89	0.969	0.056	-1.001	0.529
PK	301	3.87	0.917	0.053	-1.263	1.778
PCK	301	3.92	0.888	0.051	-1.049	1.222
TCK	301	3.84	0.903	0.052	-0.932	1.027
TPK	301	3.93	0.925	0.053	-1.080	0.933
TPACK	301	3.92	0.966	0.056	-1.060	0.934

As shown in Table 4, significant positive correlations existed among the constructs, indicating all six constructs (TK, CK, PK, PCK, TCK, TPK) impact TPACK. TPK, TCK, and CK had stronger correlations with TPACK (r = .501, .437, and .447, respectively), with TPK having the strongest correlation, mirroring the correlation analysis results for PETs.

Table 4. Correlation Analysis for In-service EFL Teachers

Constructs	TK	CK	PK	PCK	TCK	TPK	TPACK
TK	1						
CK	.384***	1					
PK	.344***	.465***	1				
PCK	.440***	.337***	.508***	1			
TCK	.388***	.415***	.427***	.355***	1		
TPK	.363***	.407***	.524***	.372***	.522***	1	
TPACK	.355***	.447***	.398***	.347***	.437***	.501***	1

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Overall, the correlation analysis suggests that the TPACK-related constructs were positively associated with one another within the IET group. In particular, the relatively strong relationships among TPK, CK, TCK, and TPACK may indicate that in-service teachers tend to connect technology use more closely with content delivery and classroom instruction. These findings suggest that teaching experience and continuous engagement with instructional practice may strengthen the integration of content, pedagogy, and technology among IETs.

4.2 Comparison of Pre-service and In-service EFL Teachers' TPACK

Descriptive statistics of TPACK-related dependent variables for both PETs and IETs are summarized in Figure 2. Although the means display slight deviations depending on the variables, in-service teachers typically scored higher (mean values between 3.80 and 3.93) than PETs (mean values between 3.55 and 3.69). The findings, as depicted in Table 5, point out the presence of statistically significant differences across all six TPACK constructs (F (7, 1650) = 7.109, p < .001, *Wilk's Λ* = .971, *partial η2* = 0.29).

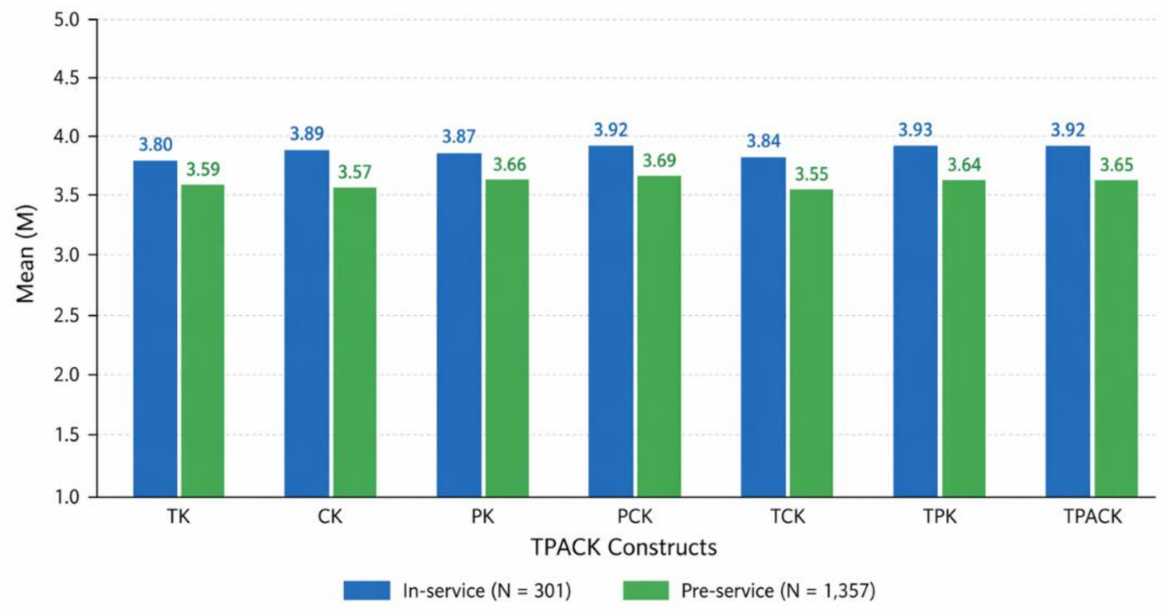

Figure 2. Descriptive Statistics for TPACK Constructs

Table 5. Multivariate Tests for TPACK Constructs

Effect	*Wilks' Λ*	*F*	*df*	*p*	*Partial η²*
Group	.971	7.11	(7, 1650)	< .001	.029

Prior to conducting MANOVA and follow-up ANOVAs, Levene's test was conducted to examine the assumption of homogeneity of variance across the two groups. As seen in Table 6, the results indicated that the variance distributions for the TPACK constructs were reasonably comparable between PETs and IETs. In addition, the descriptive statistics showed relatively similar standard deviation ranges across the two groups, with PETs ranging from .793 to .827 and IETs ranging from .831 to .969, suggesting no substantial heterogeneity of variance despite the unequal sample sizes.

Table 6. Levene's Test for TPACK Constructs

Constructs	*F*	*p*
TK	1.82	.177
CK	2.11	.146
PK	0.94	.332
PCK	1.37	.242
TCK	2.48	.116
TPK	1.65	.199
TPACK	1.91	.167

Table 7 further illustrates that there are statistical differences between in-service and PETs' TPACK constructs (TK (F (1, 1656) = 16.423, p < .001, *partial* $\eta 2$ = 0.10), CK (F (1, 1656) = 35.571, p < .001, *partial* $\eta 2$ = 0.21), PK (F (1, 1656) = 16.436, p < .001, *partial* $\eta 2$ = 0.10), PCK (F (1, 1656) = 18.855, p < .001, *partial* $\eta 2$ = 0.11), TCK (F (1, 1656) = 30.387, p < .001, *partial* $\eta 2$ = 0.18), TPK (F (1, 1656) = 28.707, p < .001, *partial* $\eta 2$ = 0.17), and TPACK (F (1, 1656) = 25.682, p < .001, *partial* $\eta 2$ = 0.15)). As seen in Table 8, the partial eta squares values for TK (.010), PK (.010), and PCK (.011) suggest medium effect sizes, whereas the values for CK (.021), TCK (.018), TPK (.017), and TPACK (.015) imply large effect sizes (Menard 2002). These effect sizes denote that the observed differences in the dependent variables can largely be accounted for by the independent variable, that is, the differential grouping of PETs and IETs.

Table 7. Multivariate Test of Group Differences on TPACK Constructs

Effect	*Wilks' Λ*	*F*	*df*	*p*	*Partial* η^2
Group	.972	24.68	(7, 1651)	< .001	.028

Table 8. Follow-up Univariate ANOVA Results for TPACK Constructs

Constructs	F	*p*	Partial η^2
TK	16.42	< .001	.010
CK	35.57	< .001	.021
PK	16.44	< .001	.010
PCK	18.86	< .001	.011
TCK	30.39	< .001	.018
TPK	28.71	< .001	.017
TPACK	25.68	< .001	.015

More specifically, the largest group differences were observed in CK, TCK, TPK, and TPACK, suggesting that in-service teachers demonstrate stronger capabilities in integrating content knowledge with pedagogical and technological practices. This pattern may reflect the role of teaching experience, as in-service teachers are more likely to have had opportunities to apply subject knowledge in authentic classroom contexts and to experiment with technology integration in practice. In contrast, PETs, despite having theoretical exposure to TPACK components, may have fewer opportunities to develop these integrated competencies through real teaching experiences.

5. Discussion

This study addresses gaps in the existing literature by providing a comparative analysis of TPACK development between PETs and IETs. The researchers first investigated the current levels and characteristics of PETs' and IETs' TPACK (RQ1). Then, the relationships among TPACK components and the differences between the two groups were examined (RQ2).

For RQ1, PETs demonstrated moderate levels of TPACK, with relatively stronger pedagogical knowledge but weaker integration of technology and content. This finding aligns with previous studies (e.g., Dong et al. 2014, Wang and Fu 2015), which reported that PETs often experience difficulty applying TPACK in practice. In particular, the relatively low level of TCK suggests that teacher education programs still struggle to support the integration of technology with subject content. This supports Angeli's (2005) argument that technology is often treated as an isolated domain rather than embedded within pedagogy. The findings further suggest that, for PETs, TPACK showed relatively stronger relationships with technology-related constructs. This partially contrasts with Chai et al. (2013), who reported different patterns of relationships among the TPACK components. In particular, the relatively strong correlations among TPK, TK, TCK, and TPACK are consistent with previous studies (e.g., Inan and Lowther 2010, Santos and Castro 2021). The prominence of TPK suggests that PETs tend to focus on how to use technology to support teaching processes rather than how to integrate it with specific lesson content. In addition, the relatively stronger relationships among technology-related constructs (TPK, TK, TCK) differ somewhat from Dong et al. (2015), who reported stronger relationships involving TCK among Chinese PETs. This discrepancy may reflect differences in training contexts, where greater emphasis is placed on pedagogical uses of technology rather than content integration. According to Angeli and Valanides (2009), such patterns are common in pre-service programs where instructional methods are emphasized. Overall, these findings suggest that PETs' TPACK is shaped more by technology-oriented learning experiences than by authentic integration of content, pedagogy, and technology.

For IETs, the findings indicate higher overall TPACK levels and a more balanced integration of knowledge domains, which is consistent with previous research (e.g., Ma and Baek 2020, Wu and Wang 2015). However, the pattern of predictors differs somewhat from Dong et al. (2015), who identified TCK as the strongest predictor of TPACK. At the same time, content-related constructs (CK, TCK, PCK) showed strong associations with TPACK. This finding supports Harris and Hofer's (2011) argument that teachers' use of technology is largely driven by content-related instructional goals. This suggests that IETs tend to approach technology as a means to support content delivery rather than as an independent domain of knowledge. Their daily engagement with curriculum requirements and student learning needs likely strengthens the role of content knowledge in shaping their TPACK.

For RQ2, the comparison between the two groups revealed that IETs consistently outperformed PETs across all TPACK constructs. This finding is consistent with Ma and Baek (2020), who also reported higher TPACK levels among IETs. More importantly, the results suggest that the differences between the two groups may reflect different emphases across TPACK constructs rather than simply differences in overall proficiency levels. Specifically, PETs tend to put much emphasis on technology-related constructs, whereas IETs place greater emphasis on content-related constructs. One possible explanation for this pattern relates to differences in their learning and teaching environments. PETs are primarily situated in university-based contexts, where exposure to digital tools is emphasized but opportunities for authentic classroom application are limited. In contrast, IETs operate in real classroom settings where instructional decisions are closely tied to curriculum demands and content representation (Koh and Divaharan 2011, Lim and Chai 2008). The larger gaps observed in technology-related constructs further suggest that current teacher education programs may not provide sufficient opportunities for technology-integrated teaching practice. When technology is taught as a separate skill rather than embedded within subject teaching, it becomes difficult for PETs to apply their knowledge in realistic instructional contexts. This supports Angeli's (2005) argument that technology is often treated as content to be learned rather than as a tool for teaching. These findings also align with Zeichner (2010), who emphasized the importance of practicum experiences in developing teachers' professional competence. Without sufficient opportunities for practice, PETs may struggle to transform theoretical knowledge into effective instructional strategies.

While the current study identified statistically significant differences in TPACK between pre-service and in-service EFL teachers, the findings also suggest a more fundamental theoretical implication regarding how TPACK develops across different stages of teacher learning. Rather than viewing TPACK as a static combination of technological, pedagogical, and content knowledge, the results of this study support the interpretation of TPACK as a dynamically constructed form of knowledge that is shaped by differences in learning contexts and professional experience.

The findings further highlight that differences between PETs and IETs should not be interpreted simply as differences in proficiency levels, but rather as differences in the underlying structure and developmental pathways of TPACK. This extends existing TPACK research by highlighting that teacher knowledge is not uniformly developed across components, but is selectively shaped by contextual affordances and constraints. From a theoretical perspective, this study contributes to the TPACK framework by providing empirical support for a context-sensitive and developmental interpretation of teacher knowledge. It suggests that TPACK should be understood not only as an integrative knowledge model, but also as a trajectory of professional learning in which different knowledge domains become more or less prominent depending on teachers' stage of experience and instructional context.

The findings of this study have several pedagogical implications for the development of TPACK among pre-service and in-service EFL teachers. First, PETs demonstrated relatively low self-efficacy in TPACK, suggesting a need to revise current teacher education programs. In particular, training should place greater emphasis on integrating technology with content knowledge. One practical approach is to incorporate case-based learning modules in which PETs design lessons that explicitly combine specific technologies with content delivery. Structured design cycles such as selecting language objectives, choosing appropriate digital tools, and refining lesson plans through feedback can help bridge the gap between theory and practice and ensure that technology is meaningfully embedded in pedagogy. Second, the results revealed different emphases across TPACK constructs between the two groups. PETs showed relatively stronger relationships among technology-related constructs, whereas IETs demonstrated relatively stronger associations with content-related constructs. However, the relatively larger gaps in technology-related constructs indicate the need to further strengthen teachers' ability to use subject-specific digital tools. To address this, teacher education programs should provide technology-focused workshops combined with mentoring and practical classroom simulations, allowing teachers to apply technology in realistic instructional contexts. For IETs, professional development should move beyond general technology training and instead focus on content-specific integration tasks. For example, teachers can redesign existing lesson materials using digital tools or transform traditional activities into interactive, technology-mediated formats. Such context-embedded tasks enable teachers to connect their strong content knowledge with effective technology integration strategies.

6. Conclusion and Further Remark

This study investigated the development of TPACK among pre-service and in-service EFL teachers in China, with a particular focus on identifying both level differences and differences in emphasis across TPACK constructs across the two groups. The findings of this study contribute to the TPACK literature by providing empirical support for a context-sensitive and developmental interpretation of teacher knowledge. Rather than viewing TPACK as a static integration of technological, pedagogical, and content knowledge, this study suggests that it should be understood as a dynamic and evolving construct, in which the relative importance of each component shifts depending on teachers' professional experience and instructional context. This perspective extends existing research by highlighting the need to examine not only overall TPACK levels but also the underlying structure and interaction of its components.

This study has several limitations. First, the data was principally gathered from only six cities in China, thereby confining the scale of the research within a comparatively small parameter. Consequently, the findings' broader applicability may be enhanced by a future study employing a larger and more diverse sample size. Second, although the present study focused on construct-level comparisons, further insights could be gained through item-level analysis. For example, identifying specific survey items that show the greatest variation between groups would help clarify which aspects of TPACK (e.g., selecting appropriate technologies, adapting content for learners, or designing technology-enhanced lessons) contribute most to the observed differences. Such analysis would also allow for the examination of variability within groups, providing a more nuanced understanding of individual differences in TPACK development. Third, important limitation of this study lies in its exclusive reliance on self-report measures to assess TPACK, which raises concerns regarding construct validity, as such measures capture teachers' perceived competence rather than their actual instructional practices. This reliance may influence the interpretation of the findings, particularly the observed differences between PETs and IETs. To address this limitation, future research should adopt more comprehensive methodological approaches, including classroom observations and/or performance-based assessments such as lesson design tasks or teaching simulations. In addition, integrating self-report data with qualitative methods, such as interviews or reflective journals, would provide a more robust and nuanced understanding of how TPACK is developed and enacted in real educational contexts.

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Examples in: English
Applicable Languages: English
Applicable Level: Tertiary

Appendix. TPACK-EFL Survey Items (Baser et al. 2016)

Constructs		Items
Technological knowledge (TK)	1	I can use basic technological terms (e.g., operating system, wireless connection, virtual memory, etc.) appropriately.
	2	I can adjust computer settings such as installing software and establishing an Internet connection.
	3	I can use computer peripherals such as a printer, a headphone, and a scanner.
	4	I can troubleshoot common computer problems (e.g., printer problems, Internet connection problems, etc.) independently.
	5	I can use digital classroom equipment such as projectors and smart boards.
	6	I can use Office programs (i.e., Word, PowerPoint, etc.) with a high level of proficiency.
	7	I can create multimedia (e.g., video, web pages, etc.) using text, pictures, sound, video and animation.
	8	I can use collaboration tools (WPS cloud files, DingTalk, Tencent conference, Wiki, Edmodo, 3D virtual environments, etc.) in accordance with my objectives.
	9	I can learn software that helps me complete a variety of tasks more efficiently.
Content knowledge (CK)	10	I can express my ideas and feelings by speaking in English.
	11	I can express my ideas and feelings by writing in English.
	12	I can read texts written in English with the correct pronunciation.
	13	I can understand texts written in English.
	14	I can understand the speech of a native English speaker easily.
Pedagogical knowledge (PK)	15	I can use teaching methods and techniques that are appropriate for a learning environment.
	16	I can design a learning experience that is appropriate for the level of students.
	17	I can support students' learning in accordance with their physical, mental, emotional, social, and cultural differences.
	18	I can collaborate with school stakeholders (students, parents, teachers, etc.) to support students' learning.
	19	I can reflect the experiences that I gain from professional development programs to my teaching process.
	20	I can support students' out-of-class work to facilitate their self-regulated learning.
Pedagogical content knowledge (PCK)	21	I can manage a classroom learning environment.
	22	I can evaluate students' learning processes.
	23	I can use appropriate teaching methods and techniques to support students in developing their language skills.
	24	I can prepare curricular activities that develop students' language skills.
	25	I can adapt a lesson plan in accordance with students' language skill levels.
Technological content knowledge (TCK)	26	I can take advantage of multimedia (e.g., video, slideshow, etc.) to express my ideas about various topics in English.
	27	I can benefit from using technology (e.g., web conferencing and discussion forums) to contribute at a distance to multilingual communities.
	28	I can use collaboration tools to work collaboratively with foreign persons (e.g., WPS cloud files, DingTalk, Tencent conference, Wiki, Edmodo, 3D virtual environments, etc.).
Technological pedagogical knowledge (TPK)	29	I can meet students' individualized needs by using information technologies.
	30	I can lead students to use information technologies legally, ethically, safely, and with respect to copyrights.
	31	I can support students as they use technology such as virtual discussion platforms to develop their higher order thinking abilities.
	32	I can manage the classroom learning environment while using technology in the class.
	33	I can decide when technology would benefit my teaching of specific English curricular standards.
	34	I can design learning materials by using technology that support students' language learning.
	35	I can use multimedia such as videos and websites to support students' language learning.
Technological pedagogical content knowledge (TPACK)	36	I can use collaboration tools (e.g., WPS cloud files, DingTalk, Tencent conference, wiki, edmodo, 3D virtual environments, etc.) to support students' language learning.
	37	I can support students as they use technology to support their development of language skills in an independent manner.
	38	I can use Web 2.0 tools (e.g., animation tools, digital story tools, etc.) to develop students' language skills.
	39	I can support my professional development by using technological tools and resources to continuously improve the language teaching process.