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Examining English as a foreign language teachers' technological pedagogical content knowledge framework in higher education in Guizhou, China

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Abstract

The technological pedagogical and content knowledge (TPACK) framework has seven distinct factors, having been empirically validated across multiple studies. Furthermore, the effects of demographic factors such as gender and age on TPACK remain ambiguous. This study investigates EFL teachers' TPACK (EFL-TPACK) framework in higher education in Guizhou, China. The objectives were to verify the validity of the seven factors of the EFL-TPACK framework, to assess the EFL-TPACK level of EFL teachers, and to explore the correlations between demographic factors and the EFL-TPACK framework. Data were collected from 286 EFL teachers across various institutions and universities in Guizhou using the adapted EFL-TPACK questionnaire. Noteworthy findings include the following: (a) the seven-factor EFL-TPACK framework was supported with acceptable fit in Guizhou, China, (b) the EFL-TPACK of EFL teachers in higher education in Guizhou was moderate level; (c) there was a correlation between demographic factors and EFL-TPACK framework; and (d) EFL teachers' majors and professional titles in Guizhou were irrelevant to EFL-TPACK framework. Hence, this research suggests that policymakers or course developers should take more demographic factors into consideration when designing professional development programs.

Keywords: EFL-TPACK, EFL teachers, Higher education, Confirmatory factor analysis (CFA), Demographic factors

Introduction

The integration of technological, pedagogical, and content knowledge (TPACK) is increasingly recognized as essential for effective teaching in modern educational settings, particularly within the realm of English as a Foreign Language (EFL) teaching. This study focuses on exploring the TPACK framework within the specific context of EFL teaching in higher education institutions in Guizhou Province, China. The primary aim is to validate the seven-factor EFL-TPACK framework, referring to the adaptation of the general TPACK framework specifically for EFL teaching, incorporating content knowledge tailored to English language instruction, and to examine EFL teachers' EFL-TPACK

and the influence of demographic factors such as gender and age on EFL teachers' EFL-TPACK level.

The surge in information and communication technology has revolutionized the educational domain, prompting extensive research on technology's role in pedagogy. This revolution emphasizes the importance of teachers' mastery of subject matter, technological fluency, and pedagogical skill—collectively termed *technological pedagogical content knowledge* (TPACK). TPACK encapsulates the essential competencies that educators must integrate to navigate the nexus of teaching, technology, and content (Mishra & Koehler, 2006). The present study delves into this triadic knowledge model relative to English as a foreign language (EFL) instruction among Guizhou's higher education institutions.

In recent years, the rapid advancements in information and communication technology have led to notable progress in pedagogical methodologies for both teaching and learning (e.g., Cha et al., 2020; Singhavi & Basargekar, 2019; Willis et al., 2019). Consequently, an instructor's proficiency in subject matter knowledge and technological insight, as well as their ability to fluidly weave technologies into the educational milieu, play a pivotal role in shaping their teaching and learning trajectory (Backfisch et al., 2020; Kali et al., 2019; Kim et al., 2022; Koehler et al., 2013). The comprehensive framework of knowledge that teachers need to incorporate technology into their teaching practices is TPACK (Koehler & Mishra, 2005; Koehler et al., 2013; Mishra & Koehler, 2006), and it illustrates a knowledge map for teachers to integrate technological, pedagogical, and content knowledge into their educational settings (Santos & Castro, 2021; Shafie et al., 2019).

Research on TPACK aids in understanding the multifaceted knowledge teachers need to integrate technology effectively into educational settings (Hilton, 2016; Lee & Kim, 2014; Schmidt et al., 2009). Given that college English is mandatory in China's higher education, the TPACK of EFL teachers is pivotal for enhancing both learning and teaching processes (Abubakir & Alshaboul, 2023; Alotumi, 2023; Wang, 2022). Well-organized technology integration requires complicated knowledge involving pedagogical knowledge and subject-matter knowledge, which is the central focus of the TPACK framework. Moreover, as one of the undeveloped provinces in China, Guizhou's education system is still inferior (Gao & Yang, 2016), not to mention EFL teaching. Many EFL teachers who graduated from non-teaching English majors have not received systematic educational training and lack basic knowledge of teaching theory and teaching methods (Chen, 2019; Yu, 2006; Zheng, 2021; Zhou, 2019). Besides, EFL teachers in Guizhou are unfamiliar with the use of technology and have little motivation to use technology to assist in teaching (Fan & Yang, 2021). When the age ranges of teachers increase, teachers become more unfamiliar with the use of technology (Kazu & Erten, 2014). Therefore, the focus of this study is this region, which is currently underrepresented in the literature. A greater understanding of EFL-TPACK within this context is important because it can provide insights into localized teaching strategies, enhance pedagogical outcomes, and address the unique challenges of EFL education in Guizhou, thereby improving the overall quality of English language education in the region.

Over the last two decades, academicians all over the world have regarded TPACK as crucial, even at the higher education level. Nevertheless, only a few quantitative studies

have used instruments to investigate EFL teachers' TPACK in higher education. Furthermore, the literature review did not reveal quantitative research about the TPACK of EFL teachers in higher education in Guizhou, China. In the current study, the TPACK survey instrument developed by Su et al. (2017) and Schmidt et al. (2009) was tailored to better align with EFL in higher education in Guizhou, China.

Despite the extensive body of literature on TPACK, many studies have focused on general education contexts, with only a few quantitative studies targeting higher education, particularly in EFL contexts. Additionally, much of the research on EFL teachers' TPACK has been conducted in more developed regions, leaving areas such as Guizhou underexplored. Prior studies often overlook the unique challenges faced by teachers in underdeveloped regions, such as limited access to technology and inadequate training in its pedagogical use (Fan & Yang, 2021). Furthermore, demographic factors like age and educational background have been underexamined in relation to their impact on EFL teachers' TPACK.

This study seeks to fill these gaps by focusing specifically on EFL teachers in Guizhou Province, using a tailored version of the TPACK survey instrument developed by Su et al. (2017) and Schmidt et al. (2009). By investigating the relationship between TPACK level and demographic variables, this research aims to contribute to the understanding of TPACK within the localized context of Guizhou's higher education system, where technology integration in EFL teaching remains underdeveloped.

Background

In recent years, the integration of technology into education has become a significant global trend, transforming traditional teaching and learning practices across all educational levels. The rapid advancement of digital tools and information technologies has presented both opportunities and challenges for educators, particularly in how they incorporate these technologies into their teaching. This integration requires teachers to not only master the subject matter but also develop proficiency in technological tools and pedagogical strategies, which together form the framework of TPACK.

TPACK

Building upon Shulman's (1986) theory of pedagogical content knowledge, Mishra and Koehler (2006) contributed to the pedagogical paradigm by integrating technological knowledge (TK) with pedagogical knowledge (PK) and content knowledge (CK). Furthermore, the TPACK framework delves into their intersections, delineating aspects such as technological pedagogical knowledge (TPK), technological content knowledge (TCK), and pedagogical content knowledge (PCK; Mishra & Koehler, 2006; Rosenberg & Koehler, 2015) (Fig. 1).

This theoretical perspective has been derived from numerous empirical studies and implementations (e.g., Chaipidech et al., 2022; Irawa et al., 2019; Qi & Wu, 2017). However, some empirical studies have failed to support the seven knowledge factors of TPACK. For instance, Valtonen et al. (2017) reported that the framework solely assessed a six-factor structure of the TPACK framework without including the direct measurement of the TPACK factor itself. Similarly, Karadeniz and Vatanartıran (2013) measured the five-factor structure of the TPACK. Furthermore, Scott and Nimon (2020) validated

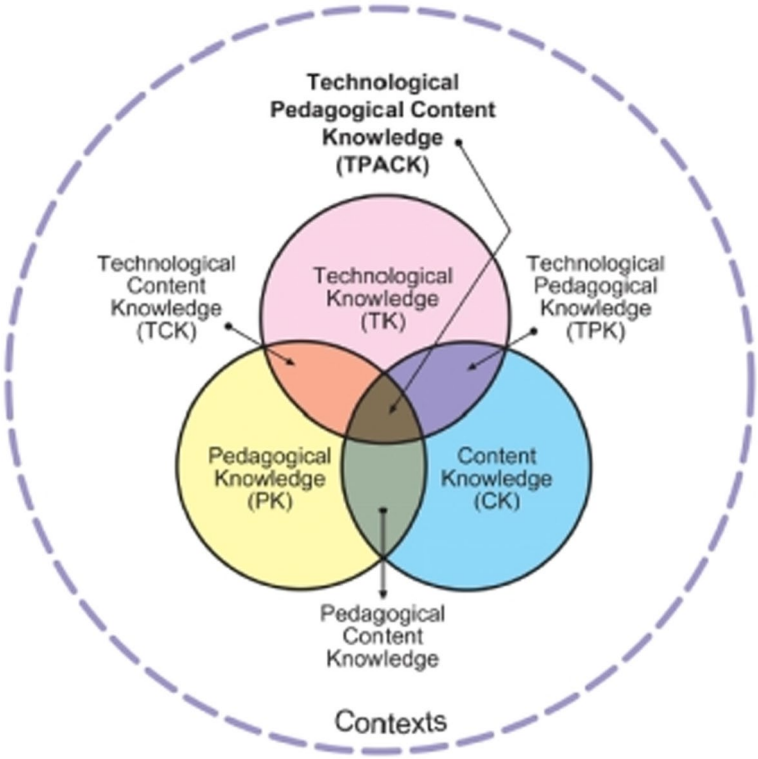

Fig. 1 The TPACK Framework. Mishra & Koehler, 2006

a four-factor framework with a sample of 1299 community college faculty members in Texas, failing the x^2 absolute fit statistic with a statistically significant *p*-value. Archambault and Barnett (2010) emphasized the difficulty in developing an instrument that can be applied universally across various contexts and subject areas for educational purposes.

As a prominent framework for examining teachers' complex knowledge structure, TPACK has garnered significant attention in research due to its intricate and comprehensive nature and the continuous emergence of novel and evolving technologies. Consequently, it is strongly advised to elucidate this framework when employing it in different subjects, populations, and contexts. Hence, the present investigation adopted the TPACK framework as the guiding structure, aligning closely with the objectives of the investigation to ascertain the optimal fit for achieving the study's aims within EFL education.

TPACK Demographics

The convergence of demographic factors and TPACK has emerged as a pivotal area of inquiry in educational research. A study by Gómez-Trigueros and De Aldecoa (2021) highlighted gender differences in digital competence of 914 trainee teachers and 194 professors, finding that female educators generally perceived themselves as having lower digital teaching competence than their male counterparts. This finding aligns with those by Bingimlas (2018), who examined Saudi teachers' TPACK knowledge among 243 participants. Generally, many studies have highlighted gender disparities

without offering detailed explanations. Consequently, the present study examined whether there was a divergence in the self-reported EFL-TPACK between males and females and determined whether such disparities correlated with other demographic variables.

Demographic factors such as gender, age, teaching experience, educational background, and training frequency significantly influence EFL teachers' TPACK (Ibrohim et al., 2022). The complex interplay between these variables shapes the landscape of TPACK. For instance, gender differences may lead to variations in technological expertise and pedagogical approaches, thus impacting the TPACK framework for both male and female EFL educators. Moreover, age and teaching experience, which are frequently correlated, may enhance or diminish technological prowess and content knowledge, creating diverse TPACK proficiencies between experienced and novice EFL teachers.

In higher-education institutions, EFL teachers' educational background and training frequency are critical factors in shaping their TPACK (Brinkley-Etzkorn, 2018). A comprehensive educational environment characterized by rigorous academic training and consistent professional development cultivates a strong TPACK framework, which allows educators to integrate technology into teaching practices effectively. Additionally, regular training can bridge technological gaps among educators, enhancing their TPACK proficiency (Brinkley-Etzkorn, 2018). Given its importance in pedagogical effectiveness, the TPACK framework for higher-education EFL educators in Guizhou requires a detailed exploration of the framework's demographic influences to foster an adaptive educational environment attuned to contemporary teaching needs.

In Guizhou, a province in China with distinct socioeconomic and cultural attributes and home to 49 of China's 56 ethnic groups (He et al., 2016), demographics play a critical role in shaping TPACK competencies. Recent research within the province reveals pronounced differences in TPACK preparedness between urban and rural educators (Young et al., 2019). Urban educators in Guizhou's tertiary institutions frequently exhibit a well-developed TPACK framework. In contrast, their rural counterparts encounter challenges due to restricted access to resources and specialized training. Huang et al. (2022) further highlighted that EFL teachers, regardless of their geographical setting, recognized the significance of technology but faced barriers in implementing TPACK strategies, reflecting broader demographic challenges such as infrastructure and training disparities.

Rationale and research questions

The literature review indicated that limited quantitative surveys have been conducted on the EFL-TPACK framework among EFL teachers in higher education in Guizhou. While a growing body of research has focused on educators in primary and secondary educational settings, there is insufficient understanding regarding the various factors that impact the EFL-TPACK of EFL teachers in higher education in Guizhou, China. Moreover, the number of knowledge factors identified in the TPACK framework appears to be associated with particular contextual considerations, such as regions and gender. Consequently, this study delved into this domain by addressing the following research questions:

- Does the EFL-TPACK of higher-education EFL teachers in Guizhou align with the TPACK framework's seven factors?
- What is the proficiency level of EFL-TPACK among higher-education EFL teachers in Guizhou, China?
- How do EFL teachers' demographics correlate with their EFL-TPACK?

Method

Instrument

The instrument employed for this study was a revised version of the TPACK survey due to its comprehensive assessment of technology integration in teaching contexts, the five-point Likert questionnaires initially designed to evaluate the TPACK of geography teachers in China by Su et al. (2017) and preservice teachers in the US by Schmidt et al. (2009). This instrument encompasses a multifaceted assessment aligned with the seven-factor framework proposed by Mishra Koehler (2006): TK, PK, CK, TPK, TCK, PCK, and TPCK. Modifications were carefully crafted to ensure relevance to EFL teachers, such as revising "I have enough knowledge of Geography" to "I have sufficient knowledge of the English language" to reflect the content-specific expertise required for EFL instruction.

A part of the questionnaire gathered demographic variables: age, gender, educational background (bachelor's degree, master's degree, or doctorate), teaching experience, and training frequency. Following the initial adjustments, the questionnaire was used as a pilot study at a private college, targeting a limited sample of EFL teachers to assess its comprehensibility. Minor modifications were made to the items during this phase. Several EFL experts also verified the questionnaire. Then, the online questionnaire was distributed in Chinese (for participant accessibility) and later translated into English for analysis and reporting, and disseminated to a WeChat group comprising EFL teachers from different colleges and universities in Guizhou.

The translation from Chinese to English was conducted by bilingual experts familiar with educational terminology, with back-translation checks to ensure accuracy and minimize potential discrepancies in meaning.

Participants

The sample consisted of 286 university teachers who teach EFL courses in Guizhou, China. The sample size was decided according to Krejcie and Morgan's (1970) sampling table: 286 respondents representing a range of institutions, including average colleges and top universities in Guizhou, with 16 public universities and 6 private universities, mostly located in Guiyang city, Zunyi city, Bijie city, Tongren city, and Anshun city. Among the participants, there were 56 female teachers (19.6%) and 230 male teachers (80.4%).

Sampling scheme and data collection

The survey was disseminated via a dedicated WeChat group, which provided access to a diverse cohort of EFL teachers spanning various higher education institutions in Guizhou Province. An invitation to participate in the survey, along with the

corresponding WeChat link, was extended to the group members. Data collection was carried out with stringent anonymity protocols in place over a period extending from August to October 2023, ensuring participant confidentiality and data integrity.

Table 1 provides the EFL-TPACK scale item-total statistics and internal consistency (Cronbach's Alpha and Omega). Ferketich (1991) recommended that the corrected item-total correlation range is between 0.30 and 0.70 for a good scale. The highest corrected item-total correlation ranges from 0.527 to 0.785, indicating that the items are moderately correlated with the total score. The Cronbach's alpha for each item ranges from 0.968 to 0.97, and the Cronbach's alpha for each factor ranges from 0.868 to 0.893, indicating that the items within each factor are highly correlated and consistently measure the same underlying construct. McDonald's Omega was also calculated for the EFL-TPACK scale, resulting in an Omega value of 0.97. This high Omega value provides further evidence that the scale reliably measures the underlying construct ($\Omega \geq 0.7$ [Dunn et al., 2014; Hayes & Coutts, 2020]).

Statistical analysis

The TPACK framework consists of seven distinct factors (Mishra & Koehler, 2006). Hence, the objective of the present study was to assess the congruity between the gathered empirical data and the underlying assumptions of the theoretical framework. Consequently, the framework's adequacy was assessed using confirmatory factor analysis with the robust maximum likelihood method. To assess the framework's goodness of fit, the hypothesized internal structure of the TPACK in relation to our populations was assessed through confirmatory factor analysis with a robust maximum likelihood (MLR) estimator. The global model fit indices were employed to assess the framework's goodness of fit: Various fit indices informed the evaluation of the model's adequacy. These included the root mean square error of approximation (RMSEA), set at a threshold of less than 0.08, as Browne and Cudec (1992) suggested. The adjusted goodness of fit index (AGFI) was expected to be greater than 0.9, in line with the recommendations of Tanaka and Huba(1985). Additionally, the standardized root mean square residual (SRMR) was kept at less than 0.05, adhering to the benchmarks proposed by Cangur and Ercan (2015). From a statistical perspective, a non-significant chi-square combined with TLI values exceeding 0.95 and RMSEA and SRMR values below 0.05 indicates a highly satisfactory model fit, as Hu and Bentler (1999) corroborated.

Kruskal–Wallis chi-squared tests were conducted on training frequency groups due to the lack of adherence to the homogeneity of variances test. The analysis was performed using post-hoc Wilcoxon signed rank tests, which were used to compare the results. Adjusted p-values (Holm, 1979) were employed to address the issue of multiple comparisons. Furthermore, a one-way ANOVA was conducted to examine the comparative influence, including educational background, gender, age, professional titles, and teaching experience. The statistical studies were performed using the SPSSAU and SPSS 28 programs.

Results

The results section consists of two parts, namely, the results of the confirmatory factor analysis and the EFL-TPACK level.

Table 1 EFL-TPACK Item-Total Statistics and Internal Consistency

Factor	Items	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha of Each Factor	Omega value
CK	CK1	.549	.969	.878	0.97
	CK2	.608	.969		
	CK3	.611	.969		
	CK4	.635	.969		
	CK5	.678	.969		
PK	PK1	.710	.969	.892	
	PK2	.714	.969		
	PK3	.658	.969		
	PK4	.660	.969		
	PK5	.591	.969		
TK	TK1	.656	.969	.868	
	TK2	.603	.969		
	TK3	.739	.969		
	TK4	.737	.969		
	TK5	.730	.969		
PCK	PCK1	.651	.969	.879	
	PCK2	.586	.969		
	PCK3	.659	.969		
	PCK4	.785	.968		
	PCK5	.730	.969		
TPK	TPK1	.677	.969	.893	
	TPK2	.729	.969		
	TPK3	.784	.968		
	TPK4	.767	.968		
	TPK5	.744	.969		
TCK	TCK1	.750	.969	.885	
	TCK2	.687	.969		
	TCK3	.685	.969		
	TCK4	.607	.969		
	TCK5	.709	.969		
TPCK	TPCK1	.778	.968	.878	
	TPCK2	.706	.969		
	TPCK3	.663	.969		
	TPCK4	.662	.969		
	TPCK5	.708	.969		
	TPCK6	.527	.970		

Table 1 (continued)

Cronbach's Alpha of .97 for the whole EFL-TPACK framework of 36 items

Table 2 Goodness-of-Fit Indices for EFL Teachers' EFL-TPACK Framework

Indices	χ^2	df	χ^2/df	RMSEA	RMR	PGFI	PNFI	PCFI	SRMR	CFI	TLI	RMSEA 90% CI
Goodness-of-Fit Indices for EFL Teachers' EFL-TPACK Framework												
Standard	–	–	< 5	< 0.10	< 0.05	> 0.5	> 0.5	> 0.5	< 0.1	> 0.9	> 0.9	–
Values	1833.127	539	3.40	0.092	0.030	0.63	0.73	0.77	0.06	0.91	0.92	0.087 ~ 0.096

Confirmatory factor analysis

Confirmatory factor analysis using the robust maximum likelihood method was executed on the EFL-TPACK variables to assess the seven-factor framework's fit. The results of the CFA are presented in Table 2.

The factorial structure of this seven-factor framework demonstrated acceptable fit, though with some limitations in certain indices, as detailed below. The relative chi-square value was within an acceptable range ($\chi 2/df = 3.40$; less than five). Other metrics also demonstrated good to acceptable fit, with the RMSEA falling between 0.08 and 0.10 (MacCallum et al., 1996). According to MacCallum et al. (1996), it was then hypothesized that an RMSEA value ranging from 0.08 to 0.10 would indicate a suboptimal fit, whereas a value below 0.08 would indicate a favorable fit. Therefore, this sample's RMSEA value of 0.092 is at the upper end of the acceptable range in educational research contexts involving complex multi-factor models and moderate sample sizes (Chen, 2007; Fan & Sivo, 2007). While the 90% CI (0.087 ~ 0.096) suggests the true value may exceed the ideal threshold of 0.08, the overall combination of indices supports the model's applicability in this specific context (SRMR < 0.08 [Hu & Bentler, 1999]; RMR < 0.09 [Hooper et al., 2008]; PGFI > 0.5 [Hooper et al., 2008]; PNFI > 0.5 [Mulaik et al., 1989]; PCFI > 0.5 [Mulaik et al., 1989]).

The chi-square value ($\chi^2 = 1833.127$, $df = 539$) is highly significant, as is common in larger samples, leading us to rely on other fit indices for evaluation (Kline, 2015). To further examine potential local misfit issues, we analyzed the standardized residual matrix and found no significant local misfits (normalized residuals < |2.58|), supporting the applicability of the seven-factor framework in this context (Byrne, 2016). However, the borderline RMSEA value suggests that the model may require further refinement in certain scenarios, and future studies could incorporate model comparisons (e.g., six-factor or five-factor structures) to verify the optimal fit.

EFL-TPACK level

To ascertain the EFL-TPACK competency levels among EFL instructors, the mean and standard deviations of the EFL-TPACK survey responses were computed (Table 2). The EFL teachers' mean score on TPCK was $\overline{X} = 4.4$, and on PCK was $\overline{X} = 3.80$, which is reasonable, and the teachers were moderate in terms of PK ($\overline{X} = 3.7$), TK ($\overline{X} = 3.7$), TPK ($\overline{X} = 3.7$), TCK ($\overline{X} = 3.7$) (Table 3).

Table 3 Descriptive Statistics of EFL Teachers' EFL-TPACK

	N	Range	Min	Max	M	SD	Variance
CK	286	3.60	1.40	5.00	3.8	0.58	0.34
PK	286	3.60	1.40	5.00	3.7	0.60	0.36
TK	286	3.40	1.60	5.00	3.7	0.64	0.42
PCK	286	2.40	2.60	5.00	3.8	0.56	0.31
TPK	286	2.40	2.60	5.00	3.7	0.57	0.32
TCK	286	2.80	2.20	5.00	3.7	0.58	0.34
TPCK	286	3.60	2.40	6.00	4.4	0.75	0.56
EFL-TPACK	286	87.00	93.00	180.00	134.16	18.05	325.82
Valid N (listwise)	286						

Range, Min, and Max refer to observed empirical values across participants; means are factor averages. Theoretical min/max for sums are 36–180 for EFL-TPACK

Table 4 Levels of EFL Teachers' EFL-TPACK

Level	Range	Number	Percentage
Lower quartile	36–120	76	26.57%
Middle quartile	121–144	140	48.95%
Upper quartile	145–180	70	24.48%

EFL teachers were grouped into three quartile levels (Table 4). The possible score range of EFL-TPACK is 36–180, but the survey results for this study produced a range of 93–180 ($M = 141$; Table 3). In this study, EFL teachers in the lower quartile were classified as having a low EFL-TPACK level, in the middle quartile as having an average EFL-TPACK level, and in the upper quartile as having a high EFL-TPACK level.

The lower quartile (36–120) comprised 76 teachers (26.57%). The middle quartile (121–144) comprised 140 teachers (48.95%), representing most of the respondents, which suggests that most EFL teachers have a moderate level of EFL-TPACK proficiency. Lastly, the upper quartile (145–180) comprised 70 teachers (24.48%).

Demographics differences

Table 5 shows the impact of EFL teachers' demographics on the EFL-TPACK and each EFL-TPACK factor via the ANOVA, Kruskal–Wallis, and Wilcoxon signed rank analyses. In particular, the ANOVA of major groups and professional title groups showed no significant differences in EFL teachers' TPACK or each factor. Similarly, educational background groups showed no significant differences in EFL teachers' TPACK and each factor except the PK factor; among EFL teachers' educational background, EFL teacher groups with a doctorate degree (mean = 19.8) and bachelor's degree (mean = 19.79) had no significant difference but both showed significant differences when compared with the EFL teachers with a master's degree (mean = 18.76). Post-hoc tests confirm no difference between doctorate and bachelor's groups, but both are significantly higher than the master's group in PK.

Although the gender difference in TPCK ($p = .019$) was statistically significant, it should be interpreted as marginal given its proximity to the conventional threshold ($p < .05$), warranting cautious interpretation, and EFL-TPACK ($F = 8.63$, $p = .04$), which

Table 5 Demographics of EFL Teachers on EFL-TPACK

Factors	Gender	Major	Age	Teaching Experience	Professional Titles	Educational Background	Training Frequency
CK	Ns	Ns	21–30: 16.86b 31–40: 19.08a 41–50: 19.54a 51–70: 20.20a	0–5: 17.04b 5–15: 19.44a ≥16: 19.81a	Ns	Ns	2 > 1, p = .02 2 < 3, p = .045
PK	Ns	Ns	21–30: 17.16c 31–40: 18.25b 41–50: 18.97b 51–70: 20.05a	0–5: 16.97b 5–15: 18.46a ≥16: 19.55a	Ns	Bachelor's 19.79a Master's: 18.76 b Doctorate: 19.8a	2 > 1, p < .02 2 < 3, p = .03
TK	Ns	Ns	Ns	Ns	Ns	Ns	2 < 3, p = .02
TCK	Ns	Ns	Ns	Ns	Ns	Ns	2 < 3, p = .02
PCK	Ns	Ns	21–30: 17.84b1–40: 18.80a 41–50: 19.92a 51–70: 19.88a	0–5: 17.76b 5–15: 18.98a ≥16: 19.98a	Ns	Ns	2 > 1, p = .02 2 < 3, p = .045
TPK	Ns	Ns	Ns	Ns	Ns	Ns	2 > 1, p = .02 2 < 3, p = .045
TPCK	Yes (F = 5.55, p = .019, marginal) Female: 22.15 Male: 20	Ns	Ns	0–5: 20.87a 5–15: 22.31a ≥16: 19.98b	Ns	Ns	2 < 3, p < .01 1 < 3, p = .018
EFL-TPACK	Yes (F = 8.63, p = .04) Female: 135.84 Male: 127.23	Ns	Ns	Ns	Ns	Ns	2 > 3, p < .01

$p < .05$, Ns = non-significant, different subscript letters reveal a statistically significant difference

both indicated that the female EFL teachers' TPCK level and EFL-TPACK level were higher than those of male EFL teachers, with the rest of the factors being non-significant.

The age group showed significant differences in CK ($p < .01$), PK ($p < .01$), and PCK ($p < .01$). EFL teachers aged 21–30 showed significantly lower CK levels than other EFL teachers over 31. EFL teachers aged 51–70 showed the highest PK level compared to other groups, and this level was statistically significant; EFL teachers aged 31–40 and 41–50 showed significantly higher PK levels than the 21–30 group, which was the lowest PK level.

The ANOVA of teaching experience groups showed significant differences in CK ($p < .01$), PK ($p < .01$), PCK ($p < .01$), and TPCK ($p = .037$). EFL teachers with teaching experience of 0–5 years showed significantly lower CK and PK levels compared to other groups. EFL teachers with teaching experience of 5–15 years showed no significant difference in CK and PK levels compared to EFL teachers with teaching experience of over 16 years, and both were significantly higher than the 0–5 group. However, the 5–15 group showed significantly higher TPCK levels than the 0–5 group and the over-16 group.

In contrast, training frequency groups did not meet the assumption of homogeneity of variances for ANOVA. Hence, Kruskal–Wallis and Wilcoxon signed rank analyses

were conducted to examine the impact of training frequency on EFL teachers' EFL-TPACK. The results showed significant differences in CK, PK, PCK, TPK, TPCK, and EFL-TPACK scores among the three groups ($p < .05$). Specifically, for CK, PK, PCK, TPK, and TPCK, Group 2 (1–5 trainings per year) had higher scores than Group 1 (0 trainings per year; $p < .05$), while Group 2 had lower scores than Group 3 ($\geq$ six trainings per year; $p < .05$). For TCK, Group 2 had lower scores than Group 3 ($p < .05$). Additionally, Group 2 had lower TPCK scores and higher EFL-TPACK scores than Group 3 ($p < .01$), and Group 1 had lower scores than Group 3 ($p < .05$). These findings suggest that increasing training frequency is associated with higher EFL-TPACK and EFL-TPACK factor scores among EFL teachers.

Discussion

A notable gap in previous research concerns the limited examination of EFL-TPACK within specific regional contexts, particularly in Guizhou, China, where few studies have rigorously validated the seven-factor framework in this setting. Furthermore, previous studies have often lacked a detailed analysis of how demographic factors such as age, gender, and teaching experience influence TPACK proficiency. This study aims to address these gaps by providing an in-depth exploration of EFL teachers' TPACK competencies in higher education within Guizhou, China.

To ensure the reliability of the findings, the dataset underwent rigorous screening before statistical analysis. Participants who completed questionnaires in exceptionally short times were removed to enhance data reliability. Additionally, considering that some teachers may indeed possess extensive teaching experience and high proficiency, outliers from teachers who provided perfect scores on the questionnaire were retained. However, their inclusion may lead to an inflation of overall EFL-TPACK proficiency estimates and a reduction in response variability, potentially affecting the sensitivity of subgroup comparisons. Despite these considerations, the refined dataset still allows for reliable results on the EFL-TPACK.

The first major result regards the validation of the seven factors of the EFL-TPACK framework (Research Question 1). The results of the confirmatory factor analysis provided empirical support for Mishra and Koehler's (2006) seven-factor framework. This alignment was observed in other studies, such as those conducted by Lin et al. (2013) and Baser et al. (2016), indicating a consistent application of the original seven-factor framework in assessing perceptions of TPACK. The sustained structural consistency of the framework across Guizhou further underscores the appropriateness of employing the seven-factor framework for survey analysis in this context. This consistency of the framework's application in diverse contexts highlights the reliability of the TPACK framework and strengthens its use as a tool for measuring technology integration proficiency among teachers.

The second significant result regards EFL Teachers' EFL-TPACK in higher education in Guizhou, China (Research Question 2). The results (Table 2) revealed a nuanced understanding of the proficiency levels of EFL-TPACK among higher education teachers in Guizhou, China. The distribution of scores across the quartiles indicates a significant spread in the TPACK competencies among EFL teachers, with nearly half possessing moderate proficiency, which is in line with Zhang and Chen's research (2022), implying

that EFL teachers in universities have a moderate and even higher level of TPACK. This insight into the current state of TPACK among EFL teachers provides a clearer foundation for developing professional development strategies aimed at enhancing technology integration.

The third major result regards the EFL teachers' demographics on their EFL-TPACK (Research Question 3). The investigation into the impact of demographic factors on EFL teachers' EFL-TPACK revealed noteworthy patterns. For example, educational background and professional titles exhibited no significant variations in overall EFL-TPACK and its individual factors, suggesting a consistent proficiency among EFL teachers across diverse educational backgrounds and professional titles, meaning that regardless of the educational major or non-educational major or what professional titles they hold, EFL teachers seem to exhibit similar proficiency of EFL-TPACK and across each EFL-TPACK factor. The reasons may be due to the job demands of EFL teaching being consistent across major groups and professional titles, and teachers may naturally develop similar skills and knowledge while teaching (Hofer & Grandgenett, 2012; Wang et al., 2018). In contrast, Gender emerged as a distinguishing factor, with female EFL teachers demonstrating higher TPCK and overall EFL-TPACK than their male counterparts. However, given the marginal significance ($p = .019$), this result should be cautiously interpreted. Although prior research (Bingimlas, 2018; Gómez-Trigueros & De Aldecoa, 2021) indicated possible gender differences in TPACK, further empirical studies specific to EFL contexts are required to substantiate these findings clearly. The explanation could be that female teachers may engage more actively in professional development, as evidenced by studies on gender differences in TPACK (Bingimlas, 2018; Gómez-Trigueros & De Aldecoa, 2021).

Age-related disparities were evident in CK, PK, and PCK, highlighting nuanced variations in specific EFL-TPACK factors across different age groups. The observed differences in CK, PK, and PCK across age groups may reflect the accumulation of content and pedagogical knowledge over time. Older teachers (51–70) likely have more teaching experience, enriching their PK (Cheng, 2017). Conversely, younger teachers (21–30) might lack the experience and depth in content knowledge (Zhang et al., 2019). The middle-aged teachers (31–50) showed higher PK than the youngest group, suggesting that the former may have found a balance between experience and modern pedagogical approaches, contributing to their enhanced pedagogical knowledge (Alqurashi et al., 2017).

Furthermore, teaching experience played a role, with EFL teachers in the initial 0–5 years showing lower CK and PK levels but a higher TPCK level, possibly due to less exposure and time to accumulate knowledge and teaching practice (Hosni, 2014). However, their higher TPCK level could be attributed to recent training in technology, openness to tech adoption, and motivation to innovate, as supported by research on novice teachers' TPACK (Joo et al., 2018; Kazu & Erten, 2014).

The study also delved into the influence of training frequency, educational background, and professional titles on EFL teachers' EFL-TPACK. While educational and professional factors demonstrated limited impact, training frequency emerged as a significant determinant of EFL-TPACK proficiency. The findings indicated variations in CK, PK, TK, PCK, TPK, TPCK, and overall EFL-TPACK scores based on training

frequency. EFL teachers engaging in training 1–5 times per year exhibited higher scores in specific factors than those without training. However, these scores were surpassed by teachers undergoing training six times or more annually. This nuanced exploration underscores the complex interplay between demographic factors, teaching experience, training frequency, and the intricate tapestry of TPACK among EFL educators. These findings suggest an association between increasing training frequency and higher EFL-TPACK scores, warranting further causal investigation.

The training frequency findings highlight the impact of consistent professional development through training on EFL teachers' EFL-TPACK proficiency. Frequent training helps teachers stay updated on pedagogical and technological advancements, enhancing their knowledge and skills across TPACK factors. It also provides a platform for addressing challenges and refining teaching strategies, illustrating the importance of continuous learning and adaptation in education.

Moreover, institutional support and local policies may also play a pivotal role in shaping the development of EFL-TPACK. Adequate policy frameworks and institutional initiatives, such as providing access to advanced technology, fostering collaborative learning environments, and incentivizing professional development, could address contextual challenges and further enhance EFL teachers' capacity for effective technology integration.

Conclusion

This study provided a comprehensive examination of the EFL-TPACK framework among EFL teachers in higher education in Guizhou, China. The findings supported the seven-factor TPACK framework and uncovered a range of competencies among EFL teachers, indicating a generally moderate level of EFL-TPACK proficiency, with variability across individuals. Additionally, the investigation into demographic influences on EFL-TPACK revealed no significant differences based on educational background and professional titles, yet gender and age were influential factors, with female teachers and different age groups exhibiting varying levels of TPACK proficiency. Moreover, teaching experience and training frequency were found to significantly impact EFL-TPACK, emphasizing the role of continuous professional development.

The study's limitations include a modest sample size predominantly representing urban areas, where most universities are located, which may restrict the generalizability of the findings, particularly to rural or less developed regions. Additionally, the skewed gender distribution (80.4% male) could affect the reliability of gender-based comparisons, potentially underpowering analyses for female subgroups and limiting generalizability. Future studies should aim for more balanced samples to address this. Furthermore, the cross-sectional design limits causal inferences, such as whether training frequency directly causes higher TPACK or reflects self-selection, and the adaptation and distribution via WeChat may introduce selection bias toward more digitally inclined participants. Lastly, reliance on self-reported data might introduce subjective biases, social desirability effects, or inaccuracies due to respondents' varying self-perceptions.

Despite these challenges, the research offers insightful observations on the variability in EFL-TPACK competencies and the rigorous methodology employed aimed to ensure the reliability of the findings.

Implications of this research underscore the need for targeted, continuous professional development programs that consider demographic differences, particularly gender, age, and training frequency, when designing strategies for enhancing TPACK proficiency for EFL teachers. Specifically, regular practice-based workshops closely aligned with classroom instruction are recommended, providing task-oriented training to help teachers master emerging digital tools and integrated pedagogical skills. Encouraging teachers to actively participate in demonstration lessons and peer-sharing seminars could foster mutual learning, further enhancing effective technology integration into teaching. Policymakers and course developers should explicitly consider demographic factors when designing professional development programs. For instance, differentiated training programs targeting teachers of varying ages should be implemented regularly, with foundational technological skills emphasized for older teachers and innovative technology integration and classroom practice emphasized for younger teachers. Furthermore, establishing a stable, long-term teacher training mechanism at the governmental or institutional level, complemented by an incentive-based reward or evaluation system, could motivate teachers to actively enhance their TPACK capabilities. Organizing cross-institutional or regional collaborative training workshops and technology-integrated teaching seminars would facilitate the normalization and concretization of technology integration into daily classroom practices.

Future research should aim to extend these findings to broader areas and develop more effective strategies for integrating educational technology, thereby optimizing teaching practices and student learning experiences in diverse educational contexts. This investigation can also be extended to explore how other factors, such as institutional support or local policies, might influence the development of TPACK across different regions. Additionally, while different regions may validate varying factors of the TPACK through CFA, it is recommended to incorporate model comparisons to ensure the best fit of the selected model. Relying solely on global model fit indices (e.g., RMSEA, PCFI) may not be sufficient to address potential local misfit issues. Therefore, future research should also explore methods to resolve local misfits, such as estimating normalized residuals, to refine the model and enhance its applicability across different educational settings.

Author contributions

Yang Mingxing conceptualized the study, conducted data collection and analysis, and wrote the main manuscript. Joanna Joseph Jeyaraj, Norhakimah Khaiessa Ahmad, and Wei Yang contributed to methodology design, data interpretation, and reviewed and edited the manuscript. All authors read and approved the final version.

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Data availability

The data supporting the findings of this study are available upon request from the corresponding author. The data are not publicly available due to their containing information that could compromise the privacy of the research participants

DeclarationsDeclarations

Ethics approval and consent to participate

The whole research is conducted in accordance with the declaration of JKEUPM (Ethic Committee For Research Involving Human Subject of University of Putra Malaysia). All procedures followed were in accordance with the ethical standards of the responsible committee of human experimentation (institutional and national) and with the Helsinki Declaration of

1975, as revised in 2000. Participants were informed of the study's purpose, procedures, potential risks and benefits, and their right to withdraw at any time. Consent to participate is not applicable.

Competing interests
There are no competing interests to declare

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