

Contextual Knowledge as a Sociocultural Filter in TPACK: Evidence from Pre-service Javanese Language Teachers

Nur Hanifah Insani^{1,*}, & Lynde Tan²

¹Department of Javanese Language and Literature Education, Universitas Negeri Semarang, Indonesia

²School of Education, Western Sydney University, Australia

*Corresponding email: hanifahnurinsani@mail.unnes.ac.id

Received: 02 December 2025

Accepted: 26 January 2026

Published: 11 February 2026

Abstract: This research examines pre-service language teachers' perceptions of technology integration through the Extended Javanese Pre-Service Teacher (X-JPST) model, which focuses on the conceptual role of Contextual Knowledge (XK) as an integral domain extension of the TPACK framework. The participants of this research were 510 pre-service Javanese language teachers from seven universities in Indonesia who had recently completed their field teaching practice course. The research employed a validated structural Likert-scale questionnaire to examine structural relationships using Partial Least Squares Structural Equation Modelling (PLS-SEM). The results show that the Technological Knowledge (TK) variable has the most significant direct influence on TPACK, followed by Technological Pedagogical Knowledge (TPK). While the direct statistical influence of XK is modest, it functions as a mediator that facilitates the application of TK. This study suggests that pre-service teachers' awareness of Javanese sociocultural factors does not directly translate into competence in technology integration. Instead, contextual knowledge operates as a foundational sociocultural filter that shapes how they perceive themselves when using technology to teach Javanese. This key finding underscores that contextual responsiveness in technology integration must be developed through the integration of multiple knowledge domains for it to contribute to their overall TPACK.

Keywords: contextual knowledge, Javanese language education, pre-service teachers, technology integration, TPACK.

Article's DOI: <https://doi.org/10.23960/jpp.v16i1.pp299-317>

■ INTRODUCTION

The landscape of global education has reached a tipping point at which technology is no longer an add-on but the very infrastructure of pedagogical change (Akram et al., 2022; Karchmer-Klein & Konishi, 2023). This shift is driven by a fundamental need to ensure that the educational system remains resilient amidst rapid socio-technical evolutions (Arifin et al., 2020; Ratih et al., 2024). Beyond the classroom walls, the integration of technology is directly tied to the survival of the next generation in the global workforce (Hidayah et al., 2020; Voogt & Roblin, 2012). However, this digital tide presents a precarious challenge for local language education,

particularly for Javanese. There is a widening disconnect in which younger generations, who are increasingly digital natives, perceive their native tongue as less relevant or even archaic amid the rapid pace of globalization (Insani et al., 2022, 2024). As noted in recent studies, this creates a significant motivational barrier in which the struggle is not merely about linguistic difficulty but also a perceived incompatibility between traditional values and modern digital life (Chen et al., 2018; Insani et al., 2025). This cultural friction necessitates a teacher's knowledge framework that is explicitly sensitive to context. Consequently, technology must be reimagined as a vital bridge (Redmond & Lock, 2019).

In Indonesia, the trend of integrating technology in the classroom is reflected in responses to the evolution of the education curriculum, which has triggered the transformation of teaching and learning approaches (Insani et al., 2022), including in Javanese language subjects at both the primary and secondary school levels. In this context, technology can expand the scope of Javanese language learning by focusing on linguistic mastery, cultural understanding, and the values of local wisdom. This aligns with the Merdeka Curriculum policy, which emphasizes project-based learning and technology-based exploration to enhance students' creativity and cultural knowledge. In addition, integrating technology into Javanese language learning is seen to improve the quality of teaching, particularly by developing students' skills, increasing engagement, and enhancing the efficiency of knowledge and information (Akram et al., 2021; Chen et al., 2018; Wang & Tan, 2023). However, to implement this, teachers need knowledge of integrating technology with pedagogical skills and mastery of the material, known as Technological Pedagogical Content Knowledge (TPACK) (Tseng et al., 2022).

The TPACK framework, as conceptualized by Mishra & Koehler (2006), represents the synergistic intersection of Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK). While the original model explicitly acknowledges that teaching and learning are situated within a specific context that is visualized as the outer circle encompassing all domains, this dimension is frequently treated as an implicit backdrop rather than an active, measurable construct in empirical research (Lee et al., 2022; Rosenberg & Koehler, 2015). In the context of local language education, such as Javanese, the instructional process is deeply embedded in complex sociocultural values, linguistic etiquette, and local philosophies that directly shape pedagogical decisions. (Insani et al., 2025).

Consequently, treating context as a peripheral factor often fails to capture the intricate dynamics of technology integration in indigenous language classrooms (Pratt & Kelly, 2016; Swallow & Olofson, 2017). Contextual knowledge is also essential for teachers to understand how students actually engage with technology rather than assuming they follow traditional processes (Tan, 2013). This study, therefore, does not suggest that the conventional framework is insufficient; rather, it aims to operationalize Contextual Knowledge (XK) as a distinct, measurable component of the framework. This approach aligns with the growing call to move beyond the internal TPACK domains to better understand the multi-layered environments, from the classroom level to the broader sociocultural landscape, in which technology integration occurs (Porrás-Hernández & Salinas-Amescua, 2013; Voogt & McKenney, 2017; Voogt & Roblin, 2012). By empirically testing the role of XK, this research aims to highlight a dimension of teacher knowledge that has historically been underemphasized in the literature on local language instruction.

This study introduces the Extended Javanese Pre-Service (X-JPST) TPACK model, which conceptualizes Contextual Knowledge (XK) not as a peripheral addition, but as an integral domain extension of the TPACK framework. While the TPACK framework has been widely recognized for its potential in technology integration, it often lacks sensitivity to cultural and situational contexts, particularly in local language education. In the X-JPST model, XK functions as a foundational sociocultural filter through which teachers align digital tools with the specific linguistic and environmental demands of their classrooms (Li & Li, 2024). In Javanese language education, XK encompasses understanding local culture and traditional values, as well as the challenges of teaching local languages to young people increasingly exposed to global culture. The addition of Contextual

Knowledge to the TPACK Plus model makes a significant contribution to this research by highlighting the importance of linking technology to the local social and cultural context in Javanese language teaching. Understanding teachers' perceptions of XK is essential to ensure that technology is not only used as a teaching tool but also as a medium to strengthen students' learning and cultural identity (Tan & Zammit, 2016).

Previous research on TPACK (Co^okun & Zeybek, 2023; Wahyuni et al., 2024; Zhang & Chen, 2022) often overlooks contextual factors, thereby reducing the applicability of the results to Javanese language teaching. By integrating XK, this study aims to provide a more comprehensive understanding of the factors that influence pre-service teachers' perceptions of integrating technology into Javanese language learning. In addition, the proposed X-JPST model serves as a reference for developing more contextually tailored teacher training programs, thereby bridging the gap between technological proficiency and cultural preservation. Consequently, this study explores how the dimensions of the X-JPST framework interact to support a sustainable, technology-based approach to teaching.

Modern education places pre-service teachers in a challenging position in which mastering technology is no longer optional but a fundamental requirement to keep pace with rapid digital shifts (Akram et al., 2022; Muschaweck, 2023). For Javanese language educators, this challenge is even more complex, as they must not only be tech-savvy but also ensure that digital tools do not erode the local cultural and social values they aim to teach. Without a clear framework for integrating ICT into these specific cultural contexts, future teachers may struggle to optimize technology in ways that truly resonate with Javanese society. This research addresses this gap by introducing the Extended Javanese Pre-Service Teacher (X-JPST) model. By

employing a PLS-SEM approach, the study uncovers the specific structural pathways, particularly the interplay between contextual knowledge and pedagogical skill, that enable teachers to master TPACK effectively. Beyond theoretical contributions, these findings offer a practical roadmap for teacher training programs to develop innovative, technology-based Javanese learning that remains deeply rooted in local wisdom.

■ METHOD

Research Question and Hypotheses

To evaluate the structural integrity and the predictive power of the X-JPST framework, this study seeks to address two overarching research questions:

- RQ1: What are the characteristic levels of the various knowledge domains within the X-JPST model as observed among pre-service Javanese teachers?
- RQ2: How do the direct and indirect structural pathways within the X-JPST model explain the development of technology integration expertise among these pre-service teachers?

Based on the proposed X-JPST framework, this study formulates the following hypotheses:

- H₁: CK positively influences TPACK.
 H₂: PK positively influences TPACK.
 H₃: TK positively influences TPACK.
 H₄: XK positively influences TPACK.
 H₅: TPK positively influences TPACK.
 H₆: TCK positively influences TPACK.
 H₇: PCK positively influences TPACK.
 H₈: PK positively influences PCK.
 H₉: CK positively influences PCK.
 H₁₀: XK positively influences PCK.
 H₁₁: TK positively influences TPK.
 H₁₂: PK positively influences TPK.

- H₁₃: XK positively influences TPK.
 H₁₄: TK positively influences TCK.
 H₁₅: CK positively influences TCK.
 H₁₆: XK positively influences TCK.
 H₁₇: TPK significantly mediates the effect of TK on TPACK.
 H₁₈: TPK significantly mediates the effect of PK on TPACK.
 H₁₉: TPK significantly mediates the effect of XK on TPACK.

Research Design

This study employed a quantitative research approach, utilizing a cross-sectional correlation survey design. This design was selected because it is well-suited to large-scale data collection, providing a comprehensive overview of specific variables and identifying statistical relationships among them (Creswell, 2017). While the survey design served as the framework for data collection, Partial Least Squares Structural Equation Modeling (PLS-SEM) was employed to analyze the complex structural relationships among the constructs in the X-JPST model. This approach enabled simultaneous testing of multiple hypotheses regarding the perceptions and TPACK understanding of pre-service Javanese language teachers.

Participants

The subjects of this study were 510 pre-service Javanese teachers enrolled in the Javanese Language Education study program and the Teacher Education Program (PPG) at various universities in Indonesia, including both state and private universities. This study employed purposive sampling to select participants in line with the research objectives. Participants were selected from Javanese Language Education students who had taken microteaching courses or would undertake the Introduction to School Field (PLP), as well as pre-service and in-service

Javanese PPG students registered at various universities in Indonesia. Participant selection criteria included educational background, teaching experience, training attended, level of teaching school, type of school, teaching location, gender, age group, length of service, and facilities available in the school to cover sufficient variation in the population of prospective Javanese language teachers. This research was conducted during 2024-2025.

Instruments

A questionnaire instrument adapted from the Center for Technology in Learning and Teaching (Li & Li, 2024; Mashhadi et al., 2023; Porras-Hernández & Salinas-Amescua, 2013; Schmidt et al., 2009) consists of 47 items used to measure prospective Javanese language teachers' understanding of TPACK and the factors that influence it. Generic pedagogical statements were contextualized to include cultural competencies, such as the digital integration of Javanese script, *geguritan* (old Javanese poetry), *sesorah* (Javanese speech), *cerkak* (Javanese short stories), *unggah-ungguh* (Javanese etiquette), and *panatacara* (Javanese master of ceremony). To ensure content validity and reliability, the adapted instrument was subject to expert judgement by specialists in Javanese linguistics and educational technology, followed by a pilot test among pre-service teachers to confirm that the items accurately captured the intersection of technology and Javanese sociocultural values.

The TPACK understanding scale includes three parts namely the first part is related to respondent demographics, including ten items; the second part associated with TPACK aspects (including nine items to measure Technology Knowledge (TK), eight items to measure Content Knowledge (CK), nine items to measure Pedagogical Knowledge (PK), five items to

measure Pedagogical Content Knowledge (PCK), four items to measure Technological Content Knowledge (TCK), nine items to measure Technological Pedagogical Knowledge (TPK), six items to measure Technology Pedagogy and Content Knowledge (TPACK) and four items to measure Contextual Knowledge (XK)); and the third part related to the perception of the use of teaching technology based on the TPACK model in the process of teaching Javanese language includes ten items. The data from the first part of the questionnaire were collected as multiple-choice items for each question.

The data from the second part of the questionnaire consisted of four Likert scales: strongly agree, agree, disagree, and strongly disagree. This forced-choice format was intentionally selected to eliminate the neutral midpoint, thereby mitigating central tendency bias. By removing the neutral option, the instrument ensures that pre-service teachers provide a clear directional perception of their TPACK competencies, which is essential for increasing the model's discriminatory power and predictive accuracy (Chyung et al., 2017). The data were collected via a questionnaire distributed via Google Forms at seven universities in Indonesia.

Table 1. TPACK and XK Construct Indicators and Sample Items

Construct	Indicators	Number of Items	Sample Item
TK (Technological Knowledge)	Proficiency in using digital hardware, software, and local font tools (e.g., Javanese script keyboards).	9	I know how to solve technical problems when using Javanese script software/apps.
CK (Content Knowledge)	Mastery of Javanese linguistics, literature, ethics (<i>unggah-ungguh</i>), and cultural philosophy.	8	I have a deep understanding of Javanese literary genres and historical contexts.
PK (Pedagogical Knowledge)	Classroom management, student assessment, and teaching strategies for language learners.	6	I can use appropriate teaching methods and techniques in the learning environment.
PCK (Pedagogical Content Knowledge)	Ability to select effective teaching approaches for specific Javanese concepts.	5	I can use appropriate teaching methods and techniques to support students in developing their language skills.
TPK (Technological Pedagogical Knowledge)	Ability to use digital tools to support general instructional goals and student engagement.	7	I can decide when technology will benefit my teaching of the curricular standards for Javanese language learning.
TPACK (Technological Pedagogical and Content Knowledge)	Integrated mastery of Javanese content using appropriate technology and pedagogy.	4	I can support my professional development by using technology tools and resources to continually improve the Javanese language teaching process.
XK (Contextual Knowledge)	Awareness of local school environments, sociocultural nuances, and student backgrounds.	4	I adapt my teaching strategies and select digital Javanese learning media based on my students' local cultural backgrounds and their feedback.

Validity and Reliability Instruments

Before analyzing the research data, the results of the validity and reliability tests of the TPACK model instrument used to measure pre-service Javanese language teachers' perceptions of their understanding of TPACK will be presented.

There were 46 questions constructed in this study. Before use, all questionnaire items must first be validated by experts. Two TPACK experts in language education reviewed the questions. For the pilot test, there were 139 students ($df = 137$); the correlation coefficient was 0.1401. By comparing the validity results of each instrument using the Pearson product-moment correlation test, it is evident that all statement items in the research questionnaire are valid. In addition, reliability was assessed using Cronbach's Alpha, which was 0.962. The alpha coefficient exceeds 0.60, indicating that the research instrument is reliable and can be used for further research. Table 1 presents complete reliability and validity test results obtained using SPSS version 27.

Data Analysis Methods

In this study, data were analyzed using PLS-SEM to simultaneously evaluate direct, indirect, specific indirect, and total effects. The decision to employ PLS-SEM rather than Covariance-Based SEM (CBSEM) was driven by several core methodological considerations. Primarily, this study focuses on predicting and explaining TPACK mastery variance rather than merely testing an established theory (Hair et al., 2020). This choice is further justified by the inherent complexity of the X-JPST model, which involves multiple paths and mediation effects across seven interrelated constructs. Furthermore, PLS-SEM provides the necessary robustness for handling survey data in the social sciences, which often deviates from a strict normal distribution (Sarstedt et al., 2022). The analytical process followed standard protocols, beginning with an evaluation

of the measurement model, focusing on convergent and discriminant validity, before proceeding to the structural model for hypothesis testing and predictive assessment.

■ RESULT AND DISCUSSION

Various TPACK Factors Observed in X-JPST Model

Before analyzing the factors influencing the TPACK levels of pre-service Javanese language teachers, it is necessary to evaluate the validity of the TPACK model developed in this study. In this case, the reliability of each indicator can also be assessed in more detail by examining the item factor loadings. While the ideal threshold suggested by Hair et al. (2019) is 0.708, indicators with loadings between 0.40 and 0.70 are acceptable if their retention does not bring the Average Variance Extracted (AVE) below the 0.50 benchmark. In this study, TK3 was removed due to its poor performance, while TK1 (0.685) and TK4 (0.653) were retained to maintain the content validity of the TK dimension. This decision is empirically justified as the AVE for the TK construct remained at 0.510, satisfying the requirement for convergent validity. Furthermore, the construct demonstrated high internal consistency, with Cronbach's alpha of 0.863, Dijkstra-Henseler's rho ($\tilde{\rho}_x$) of 0.868, and a Composite Reliability (CR) of 0.893, all of which significantly exceed the recommended threshold of 0.70. Detailed factor loadings for the remaining items are presented in Table 1.

In addition to looking at the factor loading value to see the consistency of the internal reliability of each item, it can also be seen by looking at Cronbach's alpha value (Hair et al., 2019), composite reliability (CR), and Dijkstra-Henseler's rho ($\tilde{\rho}_x$) (Rafdinal & Senalasar, 2021). Based on Cronbach's alpha, an item is considered reliable if it exceeds 0.60 (Hair et al., 2018). An item is said to be reliable and included in the "satisfactory to good" category if the CR

value is in the range of 0.70 and 0.90. (Hair et al., 2019). However, reliability values between 0.60 and 0.70 are also in the “acceptable in exploratory” category, while values above 0.95 are in the problematic category, which indicates that the item is redundant, allowing for unintended response patterns, thus reducing construct validity (Diamantopoulos et al., 2012; Drolet & Morrison, 2001; Henseler et al., 2015; Sarstedt & Wilczynski, 2009). This is not substantially different from Dijkstra-Henseler’s rho reliability value ($\tilde{\rho}_A$), where an item is considered reliable if it exceeds 0.70 (Hair et al., 2019). In the initial analysis with 42 indicator items, three items in the TK dimension had factor loadings below 0.708, reducing the Average Variance Extracted (AVE) to 0.490 and rendering the TK dimension unreliable. Therefore, to ensure the reliability of the AVE for TK, the indicator with the lowest factor loading, TK3 (0.601), is removed from the TPACK model.

After the data retesting, the Cronbach’s alpha value of all items is more than 0.6, with details of CK (0.930), PK (0.907), TK (0.863), PCK (0.914), TCK (0.705), TPK (0.900), TPACK (0.836), and XK (0.770). All CR values are also in the range of 0.835 to 0.942, with details of CK (0.942), PK (0.928), TK (0.893), PCK (0.935), TCK (0.835), TPK (0.921), TPACK (0.891), and XK (0.786), thus exceeding the CR value reliability limit of 0.70. While Dijkstra-Henseler’s rho value ($\tilde{\rho}_A$) is in the range of 0.721 to 0.935, with details of CK (0.935), PK (0.911), TK (0.868), PCK (0.917), TCK (0.721), TPK (0.901), TPACK (0.843), and XK (0.852), thus exceeding the reliability limit of Dijkstra-Henseler’s rho value ($\tilde{\rho}_A$) of 0.70. All

constructs are included in the reliable category based on Cronbach’s alpha, CR, and Dijkstra-Henseler’s rho ($\tilde{\rho}_A$), all of which exceed 0.70.

The validity test is also used to assess the validity of an instrument item. An instrument’s validity can be verified by checking the average variance extracted (AVE) value (Habibi et al., 2020; Wibisono et al., 2022). An acceptable AVE value (0.50 or higher) indicates that the structure accounts for at least 50% of the variance in its indicators. The AVE is calculated by averaging the squared loadings for the structure (Hair et al., 2018; Qiu et al., 2022; Sarstedt et al., 2022). The AVE values obtained for the seven constructs are in the range of 0.510 to 0.743, with details 0.510 (TK), 0.590 (XK), 0.626 (TPK), 0.629 (TCK), 0.671 (CK and TPACK), 0.682 (PK), and 0.743 (PCK), so that the instrument constructs are said to be valid.

The validity and reliability of the constructs were evaluated through a Confirmatory Factor Analysis (CFA) within the PLS-SEM framework. Before the analysis, as shown in Table 2, the data’s suitability for factor analysis was confirmed by a Kaiser-Meyer-Olkin (KMO) value of 0.916 and a significant Bartlett’s Test of Sphericity ($\chi^2 [510] = 18142.077, p < 0.001$). To address the requested model fit indices, the Standardized Root Mean Square Residual (SRMR) was used. The model yielded an SRMR of 0.071, below the recommended threshold of 0.08, indicating acceptable model fit (Henseler et al., 2015). The Normed Fit Index (NFI) is often lower in PLS-SEM than in CB-SEM; however, the overall metrics indicate that the X-JPST_TPACK model has sufficient structural integrity for hypothesis testing.

Table 2. Output construct validity and reliability

Construct/ Item	Loading	Cronbach’s alpha	Dijkstra-Henseler’s rho (PA)	CR	AVE
Content Knowledge (CK)		0.930	0.935	0.942	0.671
CK1	0.856				
CK2	0.839				
CK3	0.762				

CK4	0.834				
CK5	0.821				
CK6	0.845				
CK7	0.815				
CK8	0.777				
Pedagogical Knowledge (PK)		0.914	0.917	0.935	0.743
PK1	0.821				
PK2	0.810				
PK3	0.847				
PK4	0.776				
PK5	0.861				
PK6	0.838				
Technological Knowledge (TK)		0.863	0.868	0.893	0.510
TK1	0.685				
TK2	0.716				
TK4	0.653				
TK5	0.720				
TK6	0.717				
TK7	0.716				
TK8	0.741				
TK9	0.773				
Pedagogical Content Knowledge (PCK)		0.914	0.917	0.935	0.743
PCK1	0.835				
PCK2	0.845				
PCK3	0.887				
PCK4	0.899				
PCK5	0.843				
Technological Content Knowledge (TCK)		0.705	0.721	0.835	0.629
TCK1	0.833				
TCK2	0.826				
TCK3	0.715				
Technological Pedagogical Knowledge (TPK)		0.900	0.901	0.921	0.626
TPK1	0.776				
TPK2	0.800				
TPK3	0.810				
TPK4	0.818				
TPK5	0.777				
TPK6	0.754				
TPK7	0.801				
Technological Pedagogical Content Knowledge (TPACK)		0.836	0.842	0.891	0.671
TPACK1	0.812				
TPACK2	0.859				
TPACK3	0.756				
TPACK4	0.847				
Contextual Knowledge (XK)		0.770	0.786	0.852	0.590
XK1	0.760				
XK2	0.810				
XK3	0.746				
XK4	0.754				

Table 3. X-JPST model fit summary

Fit Index	Value	Threshold	Interpretation
SRMR	0.071	<0.08	Good Fit
NFI	0.678	>0.90 (Ideal)	Acceptable for PLS
KMO	0.916	> 0.70	Excellent

All variables were then classified into seven factors, namely CK, TK, PK, PCK, TCK, TPK, and TPACK. The seven dimensions supported by the CFA results corroborate the TPACK model, as proposed by Koehler et al. (2012) and Mishra & Koehler (2006). Similar findings (Castéra et al., 2020; Schmid et al., 2021; Schmidt et al., 2014) are consistent with the original seven-factor model in measuring TPACK perceptions. This relatively stable structure of the TPACK model across countries supports the use of the seven-factor model in analyzing cross-country TPACK surveys across subjects.

The seven confirmed TPACK factors were then examined for their inter-factor relationships. Pearson correlation test results (see Table 3) showed that all aspects significantly correlated (r ranged from 0.279 to 0.838). The correlation between PK and PCK ($r=0.838$) is the strongest, followed by the correlation between TPK and TPACK ($r=0.742$), TK and TPK ($r=0.723$), and PK and TPK ($r=0.682$). Overall, the seven TPACK factors in Javanese language teachers' understanding are positively correlated.

Following the assessment of the measurement model, the structural model was evaluated to determine its explanatory power, predictive relevance, and overall fit. In line with contemporary PLS-SEM methodologies (Hair et al., 2020; Hair et al., 2022), this study moved beyond the outdated Goodness-of-Fit (GoF) index and employed the SRMR to assess model fit. The analysis yielded an SRMR of 0.071, well below the established threshold of 0.08, indicating a good model fit (Henseler et al., 2015).

The model's explanatory power is reflected in the R^2 values, where the X-JPST-TPACK model explains 60.5% of the variance in TPACK mastery ($R^2 = 0.605$), categorized as a moderate to substantial effect. Additionally, the predictive relevance was confirmed through the blindfolding procedure, yielding Q^2 values ranging from 0.285 to 0.565. Since all Q^2 values are consistently above zero, the model demonstrates sufficient predictive relevance for all endogenous constructs (Table 2). These metrics collectively confirm that the X-JPST-TPACK model is statistically robust and suitable for hypothesis testing.

Table 4. The goodness of fit test results

Variable	AVE	R^2	Q^2
CK	0.671		
PK	0.682		
TK	0.510		
XK	0.590		
PCK	0.743	0.770	0.565
TCK	0.629	0.467	0.285
TPK	0.626	0.677	0.422
TPACK	0.671	0.605	0.409
Model Fit	SRMR	0.071	

Furthermore, the X-JPST-TPACK inner model was evaluated using R^2 's interpretation to assess its accuracy. The TCK variable has an effect of 0.467 (46.7%), TPACK has an impact of 0.605 (60.5%), and TPK has an effect of 0.677 (67.7%). The PCK variable has the most significant influence on the X-JPST-TPACK model, accounting for 0.770 (77.0%), while the other variables account for the remaining 23.0% (see Table 5).

Table 5 shows that the correlation between the seven TPACK factors is positive at the 0.01 significance level when tested using SPSS version 27. Among all established relationships, the closeness of relationships between factors can be mapped. Among the dimensions, the PK and PCK factors exhibit a strong relationship, with

Table 5. Correlation between TPACK dimensions in Javanese language teaching

	TK	CK	PK	PCK	TCK	TPK	TPACK	XK
TK	1							
CK	0.39*	1						
PK	0.53*	0.60*	1					
PCK	0.56*	0.68*	0.84*	1				
TCK	0.65*	0.28*	0.44*	0.40*	1			
TPK	0.72*	0.54*	0.68*	0.68*	0.60*	1		
TPACK	0.67*	0.36*	0.59*	0.55*	0.55*	0.74*	1	
XK	0.31*	0.26*	0.39*	0.36*	0.22*	0.38*	0.34*	1

* Significant at 1% significance level (2-tailed)

correlation coefficients ranging from 0.76 to 0.99. Fifteen factor relationships fall into the strong category, ranging from 0.51 to 0.75. The relationship between the TK dimension and the other five dimensions (PK, PCK, TCK, TPK, TPACK) is substantial. In contrast, TK and CK, and TK and XK, have moderately strong relationships, ranging from 0.26 to 0.50. Strong relationships also occur among CK, PK, PCK, and TP. In contrast, the relationships between CK and TCK, and between CK and XK, are not very strong or in the moderate category. The relationships between PK and TPK and between PK and TPACK are strong, while those between PK and TCK and between PK and XK are moderate. On the other hand, the relationship between XK and the other seven dimensions (TK, CK, PK, PCK, TCK, TPK, and TPACK) is moderate. This means that XK has moderate strength because its contribution to other relationships is ordinary. Similarly, the correlation between PCK and TCK is mild. In contrast, the correlation between different dimensions, namely the correlation between PCK and TPK, PCK and TPACK, TCK and TPK, TCK and TPACK, and TPK and TPACK, is high.

The SEM Model Path Analysis of X-JPST-TPACK Framework

This study uses path analysis to examine the direct, indirect, and total effects of each exogenous variable on the endogenous variables

in the SEM model. The direct impact shows the relationship between the constructs, visualized by the model's direct arrow. On the other hand, indirect effects measure how a particular variable affects other variables through mediating variables in the model (Chin, 1998; Sarstedt et al., 2022). The total impact includes direct and indirect effects, considering their combined influence on a given factor (Hair & Alamer, 2022). In line with Cohen's guidelines (Cohen et al., 2018), effect sizes are assessed using standardized values: values below 0.1 are considered small, those around 0.3 are considered medium, and values equal to or above 0.5 are considered significant.

To systematically test the NJTP-TPACK framework, the model evaluated 16 direct hypotheses and 3 specific indirect (mediation) hypotheses, for a total of 19 tested paths. The summary of the hypothesis testing, including path coefficients ($\hat{\alpha}$), T-statistics, and p-values, is presented in Table 6, while the path analysis chart is illustrated in Figure 1.

A critical finding of this study is the mechanism by which XK mediates the final TPACK outcome. While the direct path (H_{12}) was non-significant, the analysis of specific indirect effects confirmed that the path $XK \rightarrow TPK \rightarrow TPACK$ is statistically significant ($\hat{\alpha} = 0.034$, $T = 2.339$, $p = 0.020$). This indicates a full mediation effect, in which the influence of Javanese sociocultural awareness on technology integration is entirely mediated by the teacher's

ability to orchestrate technological-pedagogical strategies. This evidence solidifies the X-JPST model's premise that context is not a standalone

skill, but a foundational knowledge that enhances how teachers use digital tools in culturally sensitive ways.

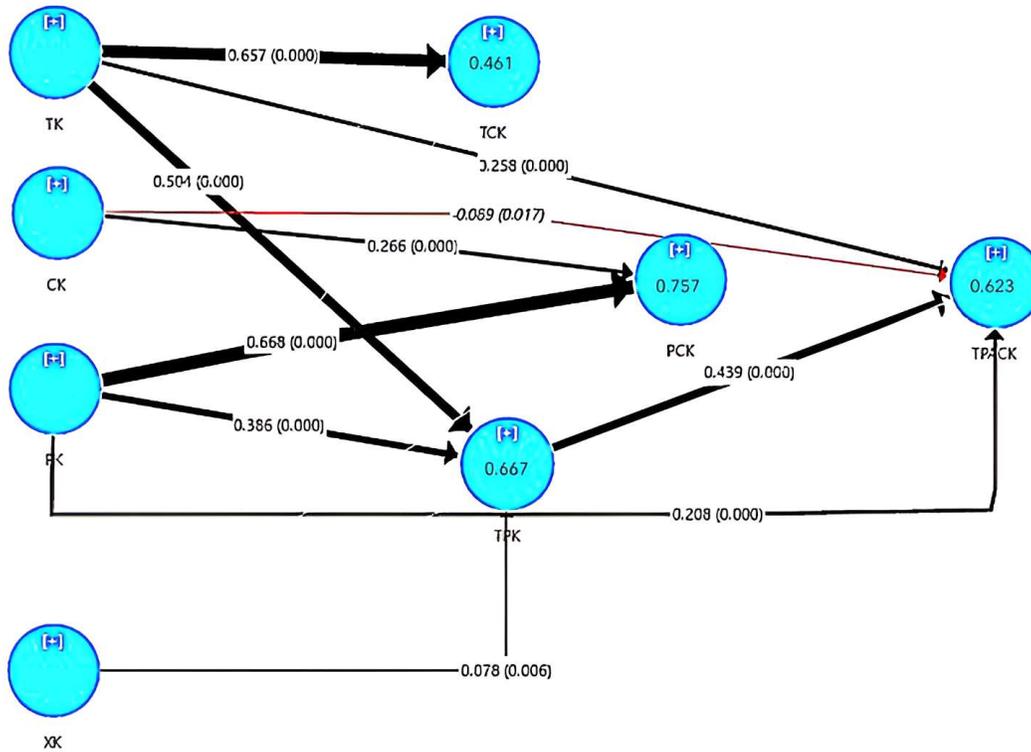


Figure 1. SEM model for the TPACK survey of prospective Javanese language teachers

Furthermore, this comprehensive analysis provides a deeper understanding of the interactions among the variables in the SEM model and explains their varying levels of influence on the endogenous variables. The findings of this study provide a comprehensive view of the relationships among the components of the TPACK framework and their collective impact on effective technology integration in Javanese language education.

Table 6 shows that two of the seven essential factors, namely PK, TK, XK, TPK, and TCK, significantly impact the TPACK of pre-service Javanese teachers. Collectively, these factors account for 62.3% of all TPACK-forming variables. In this case, TPK has a substantial positive influence on TPACK, with a significant

direct effect size of 0.439, indicating a moderate effect. These findings emphasize the critical role of pre-service Javanese teachers' TPK in improving their overall TPACK understanding, underscoring the importance of their technological pedagogical knowledge in integrating technology into Javanese language education and instruction.

The results showed a strong correlation between Pedagogical Knowledge (PK) and Pedagogical Content Knowledge (PCK) within the TPACK framework, with a correlation value of $r = 0.838$. This relationship suggests that prospective teachers with a strong understanding of pedagogy are more likely to integrate content effectively in their teaching. In the context of Javanese language education, solid pedagogical skills enable teachers to deliver Javanese language

Table 6. Hypotheses testing and structural path analysis of the X-JPST model

Outcome	Determinant	Standardized Estimates		
		Direct	Indirect	Total
TPACK (R ² = 0.623)	CK	-0.089	-0.006	-0.095
	PK	0.208	0.149	0.357
	TK	0.258	0.253	0.511
	XK	0.041	0.043	0.075
	TPK	0.439	-	0.439
	TCK	0.049	-	0.049
	PCK	-0.030	-	-0.095
PCK (R ² = 0.757)	PK	0.668	-	0.668
	CK	0.266	-	0.266
	XK	0.035	-	0.035
	TK	0.504	-	0.504
TPK (R ² = 0.667)	PK	0.386	-	0.386
	XK	0.078	-	0.078
	TK	0.657	-	0.657
TCK (R ² = 0.461)	TK	0.657	-	0.657
	CK	0.041	-	0.041
	XK	0.017	-	0.017

and cultural content, such as Javanese script, literature, and local cultural values, in a relevant and meaningful way to students. The study by Voogt and McKenney (2017) also supports these findings, showing that a strong relationship between PK and PCK facilitates the development of interactive, technology-based learning strategies in early literacy.

However, a critical anomaly arises regarding Content Knowledge (CK; $\hat{\alpha} = -0.089$) and Pedagogical Content Knowledge (PCK; $\hat{\alpha} = -0.030$). While both make positive theoretical contributions, their direct influence on TPACK in this model is either modest or inversely proportional (as seen in Table 6). From a statistical perspective, this phenomenon can be attributed to a suppressor effect. Although these direct effect sizes are not statistically significant, the total effect of PCK remains positive, suggesting that its influence on TPACK is channeled through indirect pathways. In this

causal chain, the influence of subject-specific knowledge is not direct but flows from PK to PCK and TPK before ultimately impacting TPACK (represented by the paths PK \rightarrow PCK \rightarrow TPACK and PK \rightarrow TPK \rightarrow TPACK). Because PK and TPK account for the majority of the variance in this model, they suppress the direct contribution of PCK. This suggests that for Javanese language teachers, pedagogical and technological fluency are the necessary vehicles for content expertise to manifest as technology integration. Conceptually, this aligns with the contextual realities of Javanese language education, in which teachers with high subject-matter expertise often perceive complex cultural content as best preserved through traditional face-to-face modeling to maintain authenticity, rather than through direct digital integration.

The relationship between PK and PCK can be leveraged to design teacher training programs that integrate pedagogy with local cultural content.

This training could include a storytelling approach based on Javanese folktales to teach the Javanese script. This approach improves students' understanding of the content and strengthens their connection to local culture. In addition, teachers can be trained to use technology-based projects, such as developing digital multimodal compositions on various types of Javanese literary works, thereby enabling students to develop 21st-century skills while deepening their understanding of the content (Tseng et al., 2025).

This study also shows that the Technological Pedagogical Knowledge (TPK) dimension has a significant relationship with Technological Knowledge (TK) ($\beta = 0.723$) and TPACK ($\beta = 0.742$). This suggests that teachers' mastery of technology is essential to integrating pedagogy and content in technology-based teaching. In the context of Javanese, for example, digital applications such as the Javanese script multimodal e-book (Insani et al., 2022) can support students in learning the script or broaden their cultural insights through technology-based interactive materials.

This finding aligns with Mouza et al. (2017), who found that a strong relationship between PK and PCK helped science teachers develop interactive experiments that improved students' understanding of scientific concepts. However, in Javanese language teaching, the challenge is not only the lack of appropriate digital media (Insani et al., 2024) but also significant contextual barriers at the research site. These include limited access to reliable technology in classrooms and a lack of targeted professional development in Javanese-based ICT. Furthermore, many pre-service teachers hold a belief in, or preference for, traditional teaching methods, fearing that technology may dilute the sacredness or authentic etiquette (*unggah-ungguh*) of the Javanese language. This situation stands in stark contrast to science and mathematics, which have more established technological resources and global

platforms. To bridge this gap, Javanese language teacher training programs should be strategically designed to leverage the existing strong relationship between PK and PCK, while simultaneously enhancing TPK mastery through culture-sensitive technology that respects local values.

Furthermore, despite its theoretical importance, the empirical role of Contextual Knowledge (XK) in this model is remarkably marginal. While XK shows a moderate correlation ($\beta = 0.339$) with TPACK, indicating that pre-service teachers possess a foundational awareness of the importance of context, its structural influence is remarkably marginal, evidenced by a direct path coefficient of only 0.041 and a small total effect of 0.075. According to the criteria of Chin (1998) and Hair & Alamer (2022), these results confirm that XK is not a functional driver of technology integration for this population. This discrepancy suggests a gap between perceived awareness and practical application, challenging the theoretical frameworks of Mishra (2019) and Porras-Hernández & Salinas-Amescua (2013), which position XK as a critical, active extension of the TPACK model (Habibi et al., 2020; Li & Li, 2024).

A critical finding of this study is the mechanism by which XK mediates the final TPACK outcome. While the direct path (H_{12}) was non-significant, the analysis of specific indirect effects confirmed that the path $XK \rightarrow TPK \rightarrow TPACK$ is statistically significant ($\beta = 0.034$, $T = 2.339$, $p = 0.020$). This indicates a full mediation effect (Hair et al., 2022), whereby the influence of Javanese sociocultural awareness on technology integration is entirely mediated by the teacher's ability to orchestrate technological-pedagogical strategies. This evidence solidifies the X-JPST-TPACK model's premise that context is not a standalone skill, but a foundational knowledge that enhances how teachers use digital

tools in culturally sensitive ways (Mishra, 2019; Porras-Hernández & Salinas-Amescua, 2013). This mediation underscores the importance of a sociocultural approach to teaching Javanese. Without XK as a foundational filter, technology remains a generic tool. A sociocultural approach ensures that technology serves as a medium for cultural preservation, keeping digital transformation in the classroom responsive to local values and social norms.

The necessity of this mediation, in which XK must go through TPK before impacting TPACK, can be attributed to survival mode and to specific pedagogical perceptions typical of pre-service teachers. As highlighted by Mouza et al. (2017) and Karchmer-Klein & Konishi (2023), although these educators recognize the value of sociocultural nuances (Swallow & Olofson, 2017), their perceptions are often constrained by a traditional view that positions the Javanese language and technology as distinct domains. Specifically, they struggle to find digital tools that can effectively capture the artistic nuances of *geguritan* (Javanese poetry) or the complex etiquette (*unggah-ungguh*) required in *sesorah* (Javanese formal speech). Consequently, their primary focus remains on technical fluency (TK, total effect = 0.511) and instructional stability (TPK, total effect = 0.439), rather than deep contextual integration. Furthermore, the current scarcity of technology-based media tailored to Javanese local content, such as the Javanese script (Insani et al., 2024), reinforces their reliance on conventional methods, preventing them from translating their contextual awareness into functional pedagogical actions. This explains why the direct path to XK is marginal; for pre-service teachers, XK remains a latent cultural understanding that requires TPK to mediate traditional knowledge into culturally responsive digital pedagogy.

In addition, XK can strengthen understanding of TPK by ensuring that the

integration of technology into teaching aligns with culturally appropriate pedagogical strategies. For example, digital storytelling techniques can be used to teach folklore material adapted to the cultural context in which students live. Thus, technology is not only a tool for instruction but also a medium to preserve local culture. This aligns with Mishra's (2019) findings, which emphasize that contextual alignment through XK can make technology-based learning more meaningful and engaging for students.

On the other hand, XK also strengthens PCK by helping teachers adapt instructional methods to students' sociocultural contexts. Teachers who understand XK well can design learning activities that integrate local culture, such as collaborative projects that document local history or traditions using digital technologies. Such projects not only make the material more relatable and interesting but also improve students' critical and collaborative thinking skills. This aligns with the findings of Greene & Jones (2020), who underscored XK's dual function of strengthening pedagogy and content through a cultural lens.

Moreover, XK complements TCK by helping teachers select or develop digital technologies that balance technological functionality and cultural relevance. For example, the Javanese script mobile application leverages technology to preserve local culture while enhancing instructional delivery. Li & Li (2024) found that integrating XK with TCK can enhance the usability and cultural fit of technological tools, thereby ensuring their effectiveness across diverse teaching contexts.

These findings underline the importance of including XK in the TPACK framework. Further understanding of the integration of XK in this component of TPACK can be achieved through various types of teacher training programs. This is important to ensure that the integration of XK into teaching technology goes beyond mere

functionality and promotes meaningful, culturally relevant learning experiences for students.

Overall, the findings of this study provide a solid basis for designing teacher training programs that focus on one TPACK dimension and strengthen connections among them. By integrating PK, CK, TPK, and XK, training can be geared towards producing culturally relevant, pedagogically engaging, and technologically effective teaching in Javanese language learning.

■ CONCLUSION

This study provides a comprehensive evaluation of the X-JPST model, offering a clearer understanding of how future educators navigate the intersection of technology, pedagogy, and culture. The findings reveal that while traditional domains, particularly the interplay between pedagogical and content knowledge, remain the primary pillars of teaching readiness, the integration of contextual knowledge (XK) provides a more nuanced lens through which the Javanese classroom is understood. Although the data suggest that XK functions as a modest rather than dominant anchor within the TPACK framework, its presence is vital in highlighting the complexity of indigenous language instruction. The findings suggest that many pre-service teachers still view traditional Javanese language teaching and technology as distinct and potentially incompatible domains. The perceived affordances of digital tools to authentically capture cultural nuances, such as those related to Javanese etiquette and literary works, remain limited. This disjunct means XK cannot directly influence TPACK unless it is first channeled through TPK, where teachers learn to bridge the cultural-technological divide.

By validating this framework, the research confirms that preparing teachers for the digital era involves more than technical proficiency; it requires a deep alignment between digital tools and the specific sociocultural environment in which they are implemented.

In practice, these insights advocate a shift toward holistic, project-based teacher training that integrates digital tools, such as interactive Javanese-specific applications or augmented reality, within a cultural framework to strengthen both pedagogical effectiveness and cultural identity. Building on these practical applications, future research should prioritize longitudinal and experimental designs to track the evolution of teacher competencies and measure the direct impact of the X-JPST model on student learning outcomes. Furthermore, expanding the research scope to include broader contextual factors, such as institutional policies and community support, will be essential to fully address the complexities of language preservation in an ever-changing digital landscape.

■ DECLARATION OF GENERATIVE AI USAGE IN THE WRITING PROCESS

During manuscript preparation, the authors used Grammarly to edit and enhance overall cohesion, clarity, and academic tone. The authors have reviewed and edited the content generated by this tool and assume full responsibility for the content of the published article.

■ REFERENCES

- Akram, H., Abdelrady, A. H., Al-Adwan, A. S., & Ramzan, M. (2022). Teachers' perceptions of technology integration in teaching-learning practices: A systematic review. *Frontiers in Psychology, 13*, 1–9. <https://doi.org/10.3389/fpsyg.2022.920317>
- Akram, H., Yingxiu, Y., Al-Adwan, A. S., & Alkhalifah, A. (2021). Technology integration in higher education during Covid-19: An assessment of online teaching competencies through technological pedagogical content knowledge model. *Frontiers in Psychology, 12*, 1–11. <https://doi.org/10.3389/fpsyg.2021.736522>

- Arifin, Z., Nurtanto, M., Priyatna, A., Kholifah, N., & Moh Fawaid. (2020). Technology andragogy: Work content knowledge model as a new framework in vocational education. Revised Technology Pedagogy Content Knowledge Model. *TEM Journal*, 9(2), 786. <https://doi.org/10.18421/TEM92-48Arif>
- Castéra, J., Marre, C. C., Yok, M. C. K., Sherab, K., Impedovo, M. A., Sarapuu, T., Pedregosa, A. D., Malik, S. K., & Armand, H. (2020). Self-reported TPACK of teacher educators across six countries in Asia and Europe. *Education and Information Technologies*, 25(4), 3003–3019. <https://doi.org/10.1007/s10639-020-10106-6>
- Chen, S. Y., Hung, C. Y., Chang, Y. C., Lin, Y. S., & Lai, Y. H. (2018). A study on integrating augmented reality technology and game-based learning model to improve motivation and effectiveness of learning English vocabulary. *Proceedings of the 2018 1st International Cognitive Cities Conference, IC3 2018*, 24–27. <https://doi.org/10.1109/IC3.2018.00015>
- Chin, W. W. (1998). The partial least squares approach to structural equation modeling. In G. A. Marcoulides (Ed.), *Modern Methods for Business Research* (pp. 295–336). Psychology Press.
- Cohen, L., Manion, L., & Morrison, K. (2018). *Research Methods in Education* (8th ed.). Routledge.
- Co^okun, N., & Zeybek, G. (2023). High school teachers' technological pedagogical content knowledge and self-efficacy perceptions. *Research on Education and Psychology*, 7(1), 164–181. <https://doi.org/10.54535/rep.1277313>
- Creswell, J. W. (2017). *Research design: Pendekatan kualitatif, kuantitatif, dan mixed (Research design: Qualitative, quantitative, and mixed methods approaches)*. Pustaka Pelajar.
- Diamantopoulos, A., Sarstedt, M., Fuchs, C., Wilczynski, P., & Kaiser, S. (2012). Guidelines for choosing between multi-item and single-item scales for construct measurement: a predictive validity perspective. *Journal of the Academy of Marketing Science*, 40(3), 434–449. <https://doi.org/10.1007/s11747-011-0300-3>
- Drolet, A. L., & Morrison, D. G. (2001). Do we really need multiple-item measures in service research? *Journal of Service Research*, 3(3), 196–204. <https://doi.org/10.1177/109467050133001>
- Greene, M. D., & Jones, W. M. (2020). Analyzing contextual levels and applications of technological pedagogical content knowledge (TPACK) in English as a second language subject area: A systematic literature review. *Educational Technology and Society*, 23(4), 75–88. [https://doi.org/10.30191/ETS.202010_23\(4\).0006](https://doi.org/10.30191/ETS.202010_23(4).0006)
- Habibi, A., Yusop, F. D., & Razak, R. A. (2020). The role of TPACK in affecting pre-service language teachers' ICT integration during teaching practices: Indonesian context. *Education and Information Technologies*, 25(3), 1929–1949. <https://doi.org/10.1007/s10639-019-10040-2>
- Hair, J., & Alamer, A. (2022). Partial least squares structural equation modeling (PLS-SEM) in second language and education research: Guidelines using an applied example. *Research Methods in Applied Linguistics*, 1(3), 100027. <https://doi.org/10.1016/j.rmal.2022.100027>
- Hair, J., Anderson, R., Black, B., & Babin, B. (2018). *Multivariate data analysis* (8th ed.). Cengage.
- Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle,

- C. M. (2019). When to use and how to report the results of PLS-SEM. *European Business Review*, 31(1), 2–24. <https://doi.org/10.1108/EBR-11-2018-0203>
- Hair, J. F., Howard, M. C., & Nitzl, C. (2020). Assessing measurement model quality in PLS-SEM using confirmatory composite analysis. *Journal of Business Research*, 109, 101–110. <https://doi.org/10.1016/j.jbusres.2019.11.069>
- Hair, J. F. J., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2022). A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM) [3 ed]. In *Sage Publishing* (Third). SAGE.
- Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science*, 43(1), 115–135. <https://doi.org/10.1007/s11747-014-0403-8>
- Hidayah, F. F., Imaduddin, M., Praptaningrum, D. N. W., & Ristanti, D. A. (2020). Cogenerative dialogue of cross-generation educators to improve chemistry teaching quality through technology. *Journal for the Education of Gifted Young Scientists*, 8(1), 465–487. <https://doi.org/10.17478/jegys.654941>
- Insani, N. H., Hardyanto, H., & Sukoyo, J. (2022). Facilitating reading Javanese letters skill with a multimodal Javanese digital e-book. *Advances in Social Science, Education and Humanities Research*, 640, 244–249.
- Insani, N. H., Sukoyo, J., Pratiwinindya, R. A., Husnaini, A. N., Sholihah, L. A.-M., & Kholiq, Y. N. (2025). Understanding digital technology adoption in Javanese language teaching: A UTAUT-TPACK approach. *Multidisciplinary Science Journal*, 8(6), 2026379. <https://doi.org/https://doi.org/10.31893/multiscience.2026379>
- Insani, N. H., Suwarna, & Triyono, S. (2024). A mixed-methods study of school language teachers' technology integration/ : Are they competence with TPACK in online learning environment? *Turkish Online Journal of Distance Education*, 25(3), 207–224. <https://dergipark.org.tr/tr/pub/tojde/issue/85948/1366465>
- Karchmer-Klein, R., & Konishi, H. (2023). A mixed-methods study of pre-service teachers' technology integration: Do they leverage their TPACK knowledge once entering the profession? *Journal of Research on Technology in Education*, 55(3), 490–506. <https://doi.org/10.1080/15391523.2021.1976328>
- Koehler, M. J., Shin, T. S., & Mishra, P. (2012). How do we measure TPACK? Let me count the ways. In R. N. Ronau, C. R. Rakes, & M. L. Niess (Eds.), *Educational technology, teacher knowledge, and classroom impact: A research handbook on frameworks and approaches* (pp. 16–31). IGI Global. <https://doi.org/10.4018/978-1-60960-750-0.ch002>
- Lee, H.-Y., Chung, C.-Y., & Wei, G. (2022). Research on technological, pedagogical, and content knowledge: A bibliometric analysis from 2011 to 2020. *Frontiers in Education*, 7. <https://doi.org/10.3389/educ.2022.765233>
- Li, M., & Li, B. (2024). Unravelling the dynamics of technology integration in mathematics education: A structural equation modelling analysis of TPACK components. *Education and Information Technologies*, 29(17), 23687–23715. <https://doi.org/10.1007/s10639-024-12805-w>
- Mashhadi, A., Kadhum, A. K., & Shooshtari, Z. G. (2023). Exploring technological pedagogical content knowledge among Iraqi high school English teachers/ : A

- comparative study during the Covid-19 pandemic. *Iranian Journal of Applied Language Studies*, 15(1), 141–154. <https://doi.org/10.22111/ijals.2023.45855.2356>
- Mishra, P. (2019). Considering contextual knowledge: The TPACK diagram gets an upgrade. *Journal of Digital Learning in Teacher Education*, 35(2), 76–78. <https://doi.org/10.1080/21532974.2019.1588611>
- Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, 108(6), 1017–1054. <https://doi.org/10.1111/j.1467-9620.2006.00684.x>
- Mouza, C., Nandakumar, R., Yilmaz Ozden, S., & Karchmer-Klein, R. (2017). A longitudinal examination of preservice teachers' technological pedagogical content knowledge in the context of undergraduate teacher education. *Action in Teacher Education*, 39(2), 153–171. <https://doi.org/10.1080/01626620.2016.1248301>
- Porras-Hernández, L. H., & Salinas-Amescua, B. (2013). Strengthening TPACK: A broader notion of context and the use of teachers' narratives to reveal knowledge construction. *Journal of Educational Computing Research*, 48(2), 223–244. <https://doi.org/10.2190/EC.48.2.f>
- Rafdinal, W., & Senalasar, W. (2021). Predicting the adoption of mobile payment applications during the Covid-19 pandemic. *International Journal of Bank Marketing*, 39(6), 984–1002. <https://doi.org/10.1108/IJBM-10-2020-0532>
- Ratih, I., Setyosari, P., Sa'dijah, C., & Praherdhiono, H. (2024). Technological pedagogical content knowledge of preservice elementary teachers: Relationship to self-regulation and technology integration self-efficacy. *European Journal of Educational Research*, 12(1), 159–170. <https://doi.org/10.12973/eu-jer.13.1.159>
- Redmond, P., & Lock, J. (2019). Secondary preservice teachers' perceptions of technological pedagogical content knowledge (TPACK): What do they really think? *Australasian Journal of Educational Technology*, 35(3), 45–54. <https://doi.org/10.14742/ajet.4214>
- Rosenberg, J. M., & Koehler, M. J. (2015). Context and technological pedagogical content knowledge (TPACK): A systematic review. *Journal of Research on Technology in Education*, 47(3), 186–210. <https://doi.org/10.1080/15391523.2015.1052663>
- Sarstedt, M., Ringle, C. M., Hair, J. F., Homburg, C., Klarmann, M., & Vomberg, A. (2022). Partial least squares structural equation modeling. In M. Klarmann, A. Vomberg, & C. Homburg (Eds.), *Handbook of Market Research* (pp. 587–632). Springer International Publishing. https://doi.org/10.1007/978-3-319-57413-4_15
- Sarstedt, M., & Wilczynski, P. (2009). More for less? A comparison of single-item and multi-item measures. *Die Betriebswirtschaft*, 69, 211–227.
- Schmid, M., Brianza, E., & Petko, D. (2021). Self-reported technological pedagogical content knowledge (TPACK) of preservice teachers in relation to digital technology use in lesson plans. *Computers in Human Behavior*, 115, 106586. <https://doi.org/10.1016/j.chb.2020.106586>
- Schmidt, D. A., Baran, E., Thompson, A. D., Koehler, M. J., Mishra, P., & Shin, T. (2009). Survey of preservice teachers' knowledge of teaching and technology. In

- Iowa State University.
- Schmidt, D. A., Baran, E., Thompson, A. D., Mishra, P., & Koehler, M. J. (2014). Technological pedagogical content knowledge (TPACK): The development and validation of an assessment instrument for preservice teachers. *Journal of Research on Technology in Education*, 42(2), 139–149. <https://doi.org/10.1080/15391523.2009.10782544>
- Swallow, M. J. C., & Olofson, M. W. (2017). Contextual understandings in the TPACK framework. *Journal of Research on Technology in Education*, 49(3–4), 228–244. <https://doi.org/10.1080/15391523.2017.1347537>
- Tan, L. (2013). Production-on-the-go practice: storyboarding as a retrospective and redundant school literacy activity. *Learning, Media and Technology*, 38(1), 86–101. <https://doi.org/10.1080/17439884.2011.638928>
- Tan, L., & Zammit, K. (2016). *Teaching writing and representing in the primary school years*. Pearson Australia.
- Tseng, J.-J., Chai, C. S., Tan, L., & Park, M. (2022). A critical review of research on technological pedagogical and content knowledge (TPACK) in language teaching. *Computer Assisted Language Learning*, 35(4), 948–971. <https://doi.org/10.1080/09588221.2020.1868531>
- Tseng, M. L., Tan, L., & Chou, T.-L. L. (2025). Place-based digital composing practices in multimodal pedagogy: a designed-based approach to enhancing bilingual educators' professional development. *International Journal of Bilingual Education and Bilingualism*, 1–26. <https://doi.org/10.1080/13670050.2025.2588674>
- Qiu, C. He, H. Chen, G., & Xiong, M. Xuan. (2022). Pre-service teachers' perceptions of technological pedagogical content knowledge in mainland China: A survey of teachers of Chinese as a second language. *Education and Information Technologies*, 27(5), 6367–6391. <https://doi.org/10.1007/s10639-022-10888-x>
- Voogt, J., & McKenney, S. (2017). TPACK in teacher education: Are we preparing teachers to use technology for early literacy? *Technology, Pedagogy and Education*, 26(1), 69–83. <https://doi.org/10.1080/1475939X.2016.1174730>
- Voogt, J., & Roblin, N. P. (2012). A comparative analysis of international frameworks for 21st century competences: Implications for national curriculum policies. *Journal of Curriculum Studies*, 44(3), 299–321. <https://doi.org/10.1080/00220272.2012.668938>
- Wahyuni, S., Etfita, F., Dafit, F., & Asnawi, A. (2024). Unboxing the primary English teacher's TPACK profile: instrumental design and validation. *Journal of Education and Learning (EduLearn)*, 18(3), 825–832. <https://doi.org/10.11591/edulearn.v18i3.21780>
- Wang, T., & Tan, L. (2023). The Conceptualisation of user-app interactivity in augmented reality-mediated learning: Implications for literacy education. *Sustainability*, 15(14), 10949. <https://doi.org/10.3390/su151410949>
- Wibisono, N., Arrasy, B. F., & Rafdinal, W. (2022). Predicting consumer behaviour toward digital K-pop albums: An extended model of the theory of planned behaviour. *Journal of Cultural Marketing Strategy*, 7(1), 19–33.
- Zhang, M., & Chen, S. (2022). Modeling dichotomous technology use among university EFL teachers in China: The roles of TPACK, affective, and evaluative attitudes towards technology. *Cogent Education*, 9(1). <https://doi.org/10.1080/2331186X.2021.2013396>