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Instrument Design and Validation for Enhancing Instructional Design Using the TPACK Framework: A Study in Surin Province

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Abstract

Developing effective instructional methods is crucial for teachers to enhance students' skills and content understanding. In this study, we surveyed the instructional design needs of high school students in Surin province using the TPACK (Technological Pedagogical Content and Knowledge) framework. The study aimed to achieve two primary objectives: (i) to implement TPACK-based instructional methods and assess their effectiveness in enhancing students' learning skills, and (ii) to identify strategies for adapting the instructional design to the specific educational context of students and schools in Surin province. A 35-item initial questionnaire was distributed to 160 high school students. Following reliability tests, exploratory factor analysis, and confirmatory factor analysis, the questionnaire was refined by reducing the number of items per subscale and improving the model fit. Structural equation modeling was used to examine the internal relationships among the components. The final 28-item TPACK questionnaire was validated as a reliable tool for assessing high school students' TPACK. Additionally, the observed relationships between knowledge components supported a transformative interpretation of the TPACK model, inspiring new perspectives and approaches in instructional design. The survey results also revealed students' preference for technology-integrated teaching methods, providing valuable insights for developing instructional designs emphasizing learner engagement, ultimately leading to more enjoyable and effective educational experiences.

Keywords: TPACK Framework, EFA, CFA, Self-Report Questionnaire, Instructional Design

1. Introduction

Teaching requires knowledge from various domains, particularly Content Knowledge (CK) and Pedagogical Knowledge (PK), which are traditionally regarded as separate entities. However, Shulman (Shulman, 1986) introduced the concept of "Pedagogical Content Knowledge" (PCK), emphasizing the integration of CK and PK. In PCK, teachers are expected to convey subject content effectively through appropriate teaching methods. This idea helps teachers understand how to blend both forms of knowledge to create meaningful learning experiences.

A significant shift in teaching practices emerged with the increasing role of Information and Communication Technology (ICT) in education. Digital technologies have opened new possibilities for innovative teaching and learning processes. However, they also pose challenges, as teachers must develop educational technology skills to integrate ICT into their teaching effectively. In response to these challenges, Mishra and Koehler (Mishra & Koehler, 2006a) introduced the "Technological Pedagogical Content Knowledge" (TPACK) framework. This framework expands on the original PCK model by incorporating technology, enabling teachers to combine pedagogy, content, and technology cohesively and effectively. The TPACK framework comprises three core components: PK, CK, and TK. When these elements intersect, they form four hybrid knowledge domains: PCK, TPK, TCK, and TPACK. TPACK has gained wide recognition as a framework that promotes effective teaching in the digital age (Deng & Zhang, 2023; Schmid et al., 2021). Research indicates that the TPACK framework is crucial in assisting teachers in effectively incorporating technology into their pedagogical approaches to address the needs of contemporary learners (Angeli & Valanides, 2009). Over the past 20 years, numerous studies have focused on developing tools to assess teachers' TPACK knowledge. These tools have been created to assess various domains of TPACK, both holistically and in specific subdomains such as TK, PK, CK, and TPACK (Max et al., 2023; Meroño et al., 2021; Ozturk et al., 2023; Putri et al., 2024; Ratnaya et al., 2024; Scherer et al., 2018) Meanwhile, several countries have adopted TPACK to guide teacher training programs to prepare teachers to integrate digital technologies into subject-specific teaching. These training programs have yielded positive results in enhancing teachers' skills and competencies in modern, effective teaching (Angeli & Valanides, 2009; Koehler et al., 2007; Mishra & Koehler, 2006a). Studies on TPACK further confirm that integrating technology into teaching significantly improves student learning outcomes. Developing TPACK is not just about incorporating technology into teaching but also about enabling teachers to understand and apply technological, pedagogical, and content knowledge in a balanced manner. Using technology to support teaching requires considering the subject matter, the students, and the learning context. For instance, digital tools can enrich learning experiences through activities promoting analytical thinking, collaboration, and problem-solving, essential 21st-century skills (Harris et al., 2009). Teachers with TPACK knowledge are better equipped to design instructional activities that foster these skills and adapt their instruction to cater to the unique requirements of their diverse student population.

While extensive research has explored TPACK from a teacher's (Koh & Chai, 2016; Zhang et al., 2021), limited studies have investigated how students perceive TPACK-based instructional design. Most existing studies focus on assessing teachers' self-reported TPACK competencies rather than evaluating whether students find these methods effective in engaging them in the learning process. Additionally, the development and validation of TPACK assessment tools have largely centered on teachers' knowledge, with few instruments designed to assess students' perspectives on technology-integrated learning. Moreover, the application of TPACK in specific educational contexts, such as schools in rural areas or underrepresented regions, remains underexplored. Understanding

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how students in these settings respond to TPACK-based teaching is crucial for adapting instructional designs that align with their learning needs and technological access. Although TPACK has been recognized as a valuable framework for integrating technology in education, it has its limitations (Koh & Chai, 2016; Zhang et al., 2021). One key issue is the absence of a clear methodology for practical implementation, which makes it difficult for educators to apply theoretical concepts in effective teaching practices (Polly et al., 2010; Santos & Castro, 2021). Furthermore, the ever-evolving nature of technology requires teachers to continually update their technological knowledge (Uerz et al., 2018; Wang et al., 2018), a factor that is not explicitly addressed in the TPACK framework.

This study is developing and validating an instrument to assess students' perspectives on TPACK-based instructional design in high school settings. It focuses on how high school students and teachers perceive TPACK-integrated teaching methods and how the validated instrument can improve instructional design in technology-enhanced learning environments through factor analysis. This analysis explored the relationships between the three interrelated knowledge domains: technological, pedagogical, and content knowledge. Both exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were employed to assess the validity of the factor structures related to TPACK knowledge. These analyses allowed for a comprehensive evaluation of the reliability and validity of the research instruments (Mishra & Koehler, 2006b). This research provides new insights by shifting the focus from evaluating teachers' TPACK competencies to examining the perspectives of both students and teachers regarding technology-integrated learning. This approach aligns with students' expectations and could enhance the overall effectiveness of the learning process.

2.Methodology

2.1 Participants

The TPACK survey included 160 participants, comprising science teachers and high school students in grades 10 to 12. Among the respondents, approximately 22.5% were science teachers. The student group showed a varied distribution across the grade levels: 25% were in grade 10, 25% were in grade 11, and 27.5% were in grade 12. These findings provide valuable insights for analyzing TPACK-based teaching and learning designs, ensuring that instructional approaches take into account the perspectives of both educators and students at different levels of experience.

2.2 Assessment Instrument Development Process

Technological Knowledge: This section evaluates the respondents' proficiency and confidence in using technology, particularly their ability to learn and apply various technological tools in their teaching. It also examines their desire to improve technical and problem-solving skills using technology.

Pedagogical Knowledge: This category focuses on teaching strategies and methods. It includes items that assess how well educators can engage students, apply diverse instructional techniques, and tailor lessons according to learning objectives and students' diverse needs.

Content Knowledge: This section's questions examine the respondents' mastery of subject matter content, particularly their ability to identify key concepts, explain topics using multiple examples, and demonstrate confidence in delivering content effectively.

Technological Pedagogical Knowledge: This section addresses how well teachers integrate technology with pedagogical strategies. It explores how technology can enhance student engagement, facilitate learning activities, and improve the presentation and delivery of educational content.

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Technological Content Knowledge: This section focuses on the ability to apply technology in teaching specific subject content. It includes items that assess the use of technology to achieve learning objectives, retrieve content from online sources, and employ virtual labs or simulations.

Pedagogical Content Knowledge: This category evaluates teachers' ability to connect pedagogical methods with content knowledge. It assesses how well educators can select effective teaching strategies, develop student exercises, evaluate learning outcomes, and provide feedback to address students' misunderstandings in specific subjects.

2.3 Ethical Considerations Section

This study followed ethical research guidelines to protect participants' rights and privacy. Before collecting data, we obtained ethical approval the Ethics Review Board of Surindra Rajabhat University (HE-651004). All participants received detailed information about the study's objectives, procedures, and rights as participants. All survey responses were anonymized to maintain confidentiality and anonymity, and no personally identifiable information was collected. The data were stored securely and could only be accessed by the research team. Participants had the right to withdraw from the study at any time without facing any consequences.

Table 1 A set of statements is categorized according to the TPACK framework. This assesses students' need for technology, pedagogy, and content teaching practices. Seven main categories are also presented.

Constructs	Items: Descriptions
TK	T1: I want opportunities to work on assignments or projects integrating various technologies to solve problems.
	T2: I want to be able to learn how to use various technologies quickly.
	T3: I aim to develop skills and the ability to use different types of technology effectively.
	T4: I want to develop the technical skills necessary for using technology in the classroom
	T5: I would like to learn how to use technology quickly and efficiently.
PK	P1: I want teaching methods that effectively capture and sustain students' attention and motivation.
	P2: I would prefer diverse teaching methods in the classroom.
	P3: I want teaching methods to be aligned with the learning objectives.
	P4: Teaching strategies should be adapted to accommodate diverse learners' needs and characteristics.
	P5: The learning activities should clearly outline the roles of the teacher and the student at each step.
CK	C1: I want the ability to identify the essential content knowledge for a particular subject area.
	C2: I should be able to explain the content through multiple, diverse examples.
	C3: I want confidence in delivering the subject matter with expertise.
	C4: I seek to have adequate knowledge about the subjects I teach.
	C5: I want to have knowledge and understanding of the content.
TPK	TP1: I want teachers to choose technology that is appropriate for the techniques, teaching methods, and learning of students.
	TP2: I want technology to enhance student engagement and participation in learning activities.
	TP3: I desire to design learning activities that integrate technology effectively for student use.
	TP4: Technology should be blended to improve student involvement in the learning process.
	TP5: Technology should be used to improve the effectiveness of presenting information to students.
TPK	TC1: I want to use technology to achieve the learning objectives outlined in lesson plans.

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Table 1 (Cont')

Constructs	Items: Descriptions
	TC2: I aim to select and retrieve content knowledge from various online learning resources.
	TC3: I want to use technology that promotes learning within the content.
	TC4: I aim to choose technology that promotes student learning for specific lessons.
	TC5: I want to use virtual labs to support specialized content areas.
PCK	PC1: I expect teachers to know how to select effective teaching strategies that guide student thinking and learning.
	PC2: Teachers should understand how to create exercises that help students integrate knowledge in specialized subjects.
	PC3: Teachers should proficiently assess student learning within specific content areas.
	PC4: I want teachers to manage lessons that explain the key content of the subject in a way that students can easily understand.
	PC5: Teachers should be able to identify student misunderstandings and offer appropriate feedback to address learning difficulties.
TPCK	TPC1: I want instructional designs that actively engage students in inquiry, allowing them to research, analyze, and synthesize information using technology.
	TPC2: I want teachers to design activities that allow students to collaborate, take on roles, and use technology appropriately in their teamwork.
	TPC3: I want students to be able to use technology for self-assessment purposes.
	TPC4: Feedback should be provided to students that reflect their ongoing progress and abilities.
	TPC5: Assessments should be varied or authentically designed to reflect real-world tasks and student work.

Technological Pedagogical Content Knowledge: The final section assesses the comprehensive integration of technology, pedagogy, and content knowledge. It focuses on designing learning activities that encourage student collaboration, self-assessment, and inquiry-based learning using technology. It also includes items that explore how assessments can be varied to reflect real-world tasks.

Each category contains five specific questions that target different aspects of the TPACK framework. Thus, the questionnaire provides a comprehensive tool for evaluating technology integration in teaching. The responses to these items offer insights into students' and teachers' perceptions of educators' ability to effectively integrate technological tools with pedagogical techniques for successful content delivery.

The process of developing the assessment instrument involved several key steps. Initially, the research team thoroughly reviewed relevant literature, focusing on TK, PK, CK, and TPACK measurement. The goal was to design an instrument that assessed students' and teachers' self-perceived TPACK development rather than merely their attitudes towards TPACK. To achieve this, the team adopted a survey style and approach similar to those of Schmidt's co-workers (Schmid et al., 2020, 2021; Schmidt et al., 2009) and other researchers (Bwalya et al., 2024; Kafyulilo et al., 2016; Sofyan et al., 2023), which had been widely used in previous TPACK studies. The next step involved constructing a preliminary questionnaire consisting of 35 items grouped under seven distinct factors (Table 1). The instrument was designed to capture perspectives from both teachers and students regarding TPACK-based instructional design. While some items are more applicable to teachers and others to students, the questionnaire was structured to ensure that insights from both groups could be analyzed collectively. We acknowledge that teachers and students may interpret specific statements differently due to their distinct roles in the learning process. These differences were considered during the questionnaire development to maintain clarity and relevance for both participant groups. The instrument's content validity was then evaluated by nine experts in teacher education, pedagogy, and TPACK. These experts were tasked with assessing the relevance of each item in measuring the specific domains of TPACK. Using a 4-point Likert scale (1 = "not relevant" to 4 = "highly relevant"), the experts rated each item's alignment with the domain

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it was intended to measure. To assess content validity, the item-level content validity index (I-CVI) was calculated for each item, as well as the overall scale-level content validity index (S-CVI). The I-CVI for most items exceeded the threshold of 0.80, indicating a strong level of agreement among the experts on the relevance of these items. The overall S-CVI/Ave for the scale was found to be 0.88, signifying an acceptable level of content validity across the instrument (see Table S1 in supporting information (SI)). However, three specific items—T1, P4, and TP3—were identified as having I-CVI scores below 0.80. These items, with I-CVI values of 0.778, were recommended for elimination based on expert feedback, as they did not meet the criteria for content validity. The remaining items were deemed appropriate, with I-CVIs ranging from 0.889 to 1.000, confirming their relevance for measuring TPACK in teachers and students. Table S1 provides the detailed results of each item's content validity index calculation. The table highlights the number of experts rating each item as either highly relevant (ratings 3-4) or not applicable (ratings 1-2), along with the I-CVI score for each item. The elimination of the three low-scoring items further strengthened the overall validity of the instrument, ensuring that the final questionnaire achieved satisfactory content validity for use in the study.

2.3 Data analysis

EFA and CFA were applied to validate the TPCEK instrument, ensuring a comprehensive validation process. EFA with varimax rotation was employed to explore the construct validity of the subscales, identifying underlying factors that represent the instrument's structure. Additionally, CFA was used to confirm the factor structure derived from the EFA, providing a deeper examination of the model fit and overall validity of the questionnaire. Cronbach's alpha (α) was calculated for each subscale to assess internal consistency, a widely used measure for reliability. However, recognizing the limitations of Cronbach's alpha in specific contexts (Schmid et al., 2021,Deng & Zhang, 2023), McDonald's omega (ω) was also computed to offer a more robust evaluation of reliability, particularly for non-tax-equivalent measures. Both indices provide a more comprehensive understanding of the scale's reliability. The initial version of the questionnaire comprised 33 items, with responses rated on a 5-point Likert scale, ranging from 1 ("strongly disagree") to 5 ("strongly agree"). Descriptive statistics for each item, including mean and standard deviation, were calculated to offer insights into the distribution of responses. This initial analysis was crucial for refining the instrument and ensuring each item effectively contributed to the respective constructs. These combined analyses ensured that the TPCEK instrument was valid and reliable, providing a solid foundation for further research and practical application in the educational context.

3.Results and discussions

3.1 Descriptive Statistics and Reliability Analysis

Table 2 (left) presents the descriptive statistics, including means, standard deviations, and reliability coefficients (Cronbach's alpha and McDonald's Omega) for the TPCEK questionnaire, which consists of 35 items. Each subscale demonstrated high internal consistency, with Cronbach's alpha and McDonald's Omega coefficients exceeding the threshold of 0.70, indicating that the items within each subscale are reliable measures of their respective constructs. For instance, the technological knowledge (TK) subscale, comprised of five items (T1–T5), exhibited strong reliability with a Cronbach's alpha of 0.932 and a McDonald's Omega of 0.933. Similar reliability was found in the pedagogical knowledge (PK) subscale, where the five items (P1–P5) yielded a Cronbach's alpha of 0.935 and a McDonald's Omega of 0.935. In particular, content knowledge (CK) demonstrated the highest reliability, with a Cronbach's alpha of 0.949 and McDonald's Omega of 0.949. This consistency was echoed across the technological pedagogical

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knowledge (TPK), technological content knowledge (TCK), and pedagogical content knowledge (PCK) subscales, all of which exhibited Cronbach's alpha values above 0.900. The TPCEK subscale, although comprised of fewer items, also maintained robust internal consistency, with Cronbach's alpha and McDonald's Omega values of 0.957. These results underscore the reliability of the TPCEK instrument in assessing the various knowledge domains integral to teachers' technological, pedagogical, content, and environmental knowledge competencies.

Table 2 Descriptive statistics (M, SD) and reliability coefficients (α and ω) for the TPACK questionnaire, which consists of 35 items across multiple subscales before analysis (left). The final TPACK questionnaire is also presented (right).

The initial TPAKC questionnaire (35 items)					The final TPAKC questionnaire (28 items)				
	Mean	SD	α	ω		Mean	SD	α	ω
T1	3.794	0.972	0.932	0.933	T2	3.931	0.905	0.923	0.924
T2	3.931	0.905			T3	3.888	0.883		
T3	3.888	0.883			T4	3.806	0.987		
T4	3.806	0.987			T5	3.950	0.923		
T5	3.950	0.923							
P1	3.925	0.843	0.935	0.935	P1	3.925	0.843	0.862	0.862
P2	3.975	0.868			P2	3.975	0.868		
P3	3.975	0.861			P3	3.975	0.861		
P4	3.969	0.857							
P5	3.938	0.852							
C1	4.106	0.806	0.949	0.949	C1	4.106	0.806	0.949	0.949
C2	4.038	0.846			C2	4.038	0.846		
C3	4.006	0.781			C3	4.006	0.781		
C4	3.944	0.795			C4	3.944	0.795		
C5	3.963	0.823			C5	3.963	0.823		
TP1	4.031	0.842	0.951	0.951	TP1	4.031	0.842	0.927	0.926
TP2	4.019	0.850			TP2	4.019	0.850		
TP3	4.038	0.784			TP4	3.988	0.869		
TP4	3.988	0.869			TP5	3.981	0.820		
TP5	3.981	0.820							
TC1	4.038	0.846	0.949	0.949	TC1	4.038	0.846	0.880	0.884
TC2	4.019	0.828			TC2	4.019	0.828		
TC3	3.975	0.861			TC3	3.975	0.861		
TC4	3.950	0.807			TC4	3.950	0.807		
TC5	3.931	0.840							
PC1	3.944	0.795	0.951	0.950	PC1	3.944	0.795	0.951	0.950
PC2	4.050	0.815			PC2	4.050	0.815		
PC3	3.956	0.827			PC3	3.956	0.827		
PC4	3.994	0.805			PC4	3.994	0.805		
PC5	4.019	0.835			PC5	4.019	0.835		
TPC1	3.931	0.833	0.957	0.957	TPC1	3.931	0.833	0.873	0.873
TPC2	3.931	0.825			TPC2	3.931	0.825		
TPC3	4.000	0.824			TPC5	3.950	0.860		
TPC4	3.988	0.801							
TPC5	3.950	0.860							

After conducting (I-CVI and S-CVI analysis and removing items that did not meet the factor loading criteria, the final version of the TPCEK instrument was refined to 28 items (see Table 2 (right)). The revised questionnaire maintained its structural integrity, with seven subscales but fewer items in specific domains. Notably, the TK subscale was reduced to four items (T2–T5), yet it still exhibited strong internal consistency, with a Cronbach's alpha of 0.923 and a McDonald's Omega of 0.924. Similarly, the PK subscale now contains three items (P1–P3), with a Cronbach's alpha of 0.862, indicating slightly lower but acceptable reliability. The CK, TPK, and PCK subscales retained high-reliability scores, with Cronbach's alpha values of 0.949, 0.927, and 0.951, respectively. Overall, the

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final 27-item instrument maintained high internal consistency across all knowledge domains, confirming its suitability for evaluating teachers' TPACK.

3.2 Exploratory Factor Analysis

To examine the underlying structure of the TPCEK instrument, an exploratory factor analysis (EFA) was conducted using principal component analysis (PCA) with varimax rotation (see Table 3). The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.960, indicating that the sample size was sufficient for factor analysis. Additionally, Bartlett's test of sphericity was significant (BTS value = 6890.4, $p < .001$), supporting the factorability of the correlation matrix. The EFA revealed a seven-factor solution, accounting for 71% of the total variance in the data. Factor loadings greater than 0.45 are reported, demonstrating the clarity of item associations with their respective constructs. For instance, items related to PCK (PC1–PC5) loaded strongly onto the first component, with factor loadings ranging from 0.571 to 0.714. Similarly, items associated with TK (T2–T5) exhibited high loadings on the second component, with loadings between 0.723 and 0.827. The TPK and TCK subscales were also well-represented, with items loading significantly onto components 3 and 4, respectively. However, Certain items, such as TPC5, demonstrated cross-loadings, indicating some overlap between the TPACK and TK constructs. This overlap may arise from the interconnected nature of the components within TPACK, where TK is often integrated into pedagogical and content-related applications. Cross-loadings imply that some items may reflect multiple dimensions of TPACK simultaneously, showing that TPACK components are not always distinct but often function in an integrated manner. We carefully reviewed the items showing cross-loadings to address this issue and concluded that their theoretical alignment with the primary construction justified their retention. Furthermore, CFA supported the factor structure, indicating that, despite minor overlaps, the constructions remain theoretically sound and distinguishable. This finding suggests that the observed cross-loadings do not significantly undermine the instrument's validity; rather, they highlight the interconnected nature of TPACK.

The correlations among the seven knowledge domains were examined to assess the interrelationships between the constructs (see Table 4). All subscales were significantly correlated, with correlation coefficients ranging from 0.638 to 0.820. The strongest correlations were observed between CK and PCK ($r = 0.815$) and between CK and TCK ($r = 0.770$), suggesting a close relationship between teachers' content knowledge and their ability to integrate content with pedagogical and technological expertise. The TK subscale also demonstrated moderate to strong correlations with other subscales, particularly with PK ($r = 0.680$) and CK ($r = 0.699$). These findings indicate that teachers with strong technological knowledge are likely to have corresponding pedagogical and content knowledge strengths, highlighting the interconnected nature of these competencies. The TPCEK subscale was significantly correlated with all other domains, with the most substantial relationship observed with PCK ($r = 0.780$), suggesting that environmental knowledge plays a crucial role in enhancing teachers' ability to integrate pedagogical content knowledge with technological tools.

The results of the exploratory factor analysis and reliability assessments provide robust evidence for the validity and reliability of the TPCEK instrument. The seven-factor solution aligns well with the theoretical framework of technological pedagogical content knowledge, including environmental knowledge as a key component. The high-reliability scores and the clear factor structure suggest that this instrument is well-suited for assessing teachers' competencies in integrating technology, pedagogy, content, and environmental considerations in their teaching practices. Future research could build on these findings by conducting CFA to validate the instrument's structure further. Additionally, longitudinal

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studies could explore how teachers' TPCEK competencies evolve and the impact of professional development interventions on enhancing these skills.

Table 3 The revised TPACK questionnaire using EFA. The factor loadings for items that load onto seven distinct components, with only loadings greater than 0.45, are displayed.

	Component						
	C1	C2	C3	C4	C5	C6	C7
PC2	0.714						
PC5	0.607						
PC3	0.598						
PC1	0.587						
PC4	0.571						
T5		0.827					
T4		0.801					
T3		0.755					
T2		0.723					
TP5			0.699				
TP4			0.678				
TP1			0.581				
TP2			0.537				
C3				0.720			
C4				0.671			
C5				0.622			
C1				0.565			
C2				0.560			
TC2					0.745		
TC3					0.697		
TC4					0.622		
TC1					0.548		
P2						0.707	
P3						0.636	
P1						0.560	
TPC2							0.568
TPC1							0.486
TPC5		0.479					0.461

The results of the exploratory factor analysis and reliability assessments provide robust evidence for the validity and reliability of the TPCEK instrument. The seven-factor solution aligns well with the theoretical framework of technological pedagogical content knowledge, including environmental knowledge as a key component. The high-reliability scores and the clear factor structure suggest that this instrument is well-suited for assessing teachers' competencies in integrating technology, pedagogy, content, and environmental considerations in their teaching practices. Future research could build on these findings by conducting CFA to validate the instrument's structure further. Additionally, longitudinal studies could explore how teachers' TPCEK competencies evolve and the impact of professional development interventions on enhancing these skills.

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Table 4 shows the correlation coefficients between the seven main components of the TPACK framework: TK, PK, CK, TPK, TCK, PCK, and TPACK. The values range from 0 to 1, illustrating the strength and direction of the relationships between these components.

	TK	PK	CK	TPK	TCK	PCK	TPACK
TK	1.000						
PK	0.680	1.000					
CK	0.699	0.710	1.000				
TPK	0.699	0.787	0.779	1.000			
TCK	0.658	0.750	0.770	0.798	1.000		
PCK	0.659	0.736	0.815	0.816	0.820	1.000	
TPACK	0.638	0.714	0.759	0.797	0.782	0.780	1.000

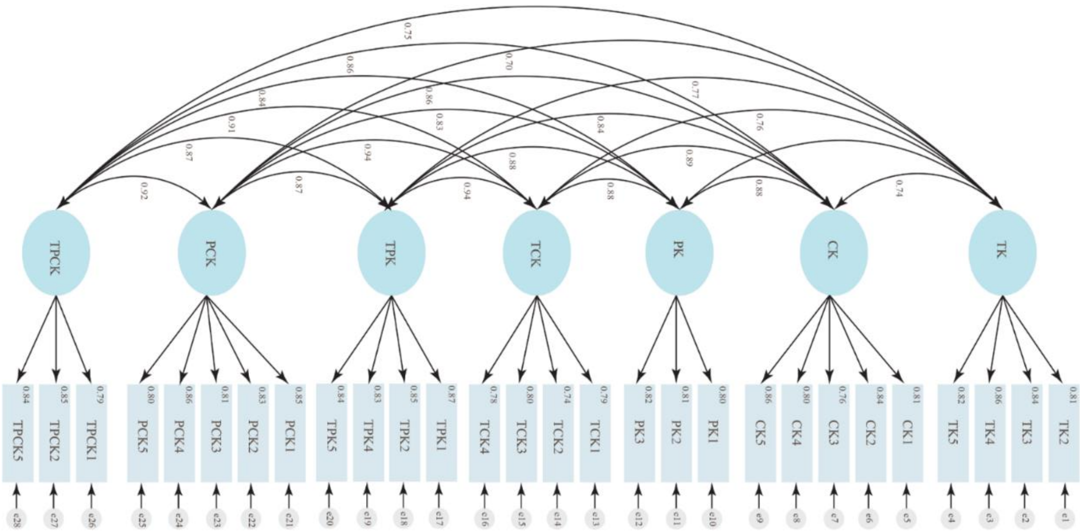

Figure 1 TPACK assessment instrument confirmatory factor analysis results.

3.3 Confirmatory Factor Analysis

To confirm the factor structure identified in the EFA, a CFA was evaluated the fit of the final model. Figure 1 presents the item loadings onto their respective constructs, along with the correlations between all latent variables and the correlated residuals. The model fit indices indicate that the structural equation model achieved an acceptable fit, thereby confirming the construct validity of the TPCEK measures. The fit index demonstrated excellent overall model fit, with $\chi 2/df = 0.379$, Comparative Fit Index (CFI) = 1.00, Tucker-Lewis Index (TLI) = 1.095, and Root Mean Square Error of Approximation (RMSEA) = 0.00, as shown in Table 8. The Standardized Root Mean Square Residual (SRMR) value of 0.05 and the Goodness of Fit Index (GFI) of 0.961 supported the model's acceptability. These fit indices are within acceptable and excellent ranges, indicating that the data fit the hypothesized seven-factor model well. The final structural equation model confirmed the appropriateness of the seven-factor solution, explaining a significant portion of the variance in the TPCEK framework. The analysis revealed that TK**4**, PK**3**, CK**5**, TCK**3**, PCK**4**, TPK**1**, and TPCK**2** are the most significant factors aligning with students' expectations. Students and teachers desired to integrate knowledge in technology, pedagogy, and content through a comprehensive approach based on the TPACK framework to design learning. They emphasized the importance of leveraging technology to enhance content learning, designing appropriate and engaging activities, and managing instructional delivery to ensure clarity and alignment with defined learning objectives.

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These results strongly support the TPCEK instrument's validity in measuring the intended constructs, making it a valuable tool for assessing technological, pedagogical, and content knowledge with an environmental emphasis in educational contexts.

As illustrated in Figure 2 (inserted image), there are notable correlations between the latent variables, indicating that internal relationships exist among the different components of TPCEK. These interconnections suggest that the various dimensions of technological, pedagogical, and content knowledge are not isolated but function as an integrated system. From a transformative perspective, TPACK is conceptualized as a unique and distinct form of knowledge that transcends the boundaries of individual knowledge components. This view highlights the complex nature of TPACK, which emerges from the interaction of technological, pedagogical, and content knowledge instead of simply being the sum of its parts. In this model, the higher-order hybrid components—Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), and Pedagogical Content Environmental Knowledge (PCK)—are shown to have a direct influence on the development of TPACK. These high-level components represent more integrated forms of knowledge that blend the core elements of TPCEK in meaningful ways. Conversely, the foundational components—Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK)—are considered core or low-level components and do not directly influence TPACK. Instead, they serve as the building blocks that underpin the hybrid components but lack the transformative integration required for directly shaping TPACK.

As shown in Figure 2, the structural equation modeling (SEM) results support this theoretical framework by revealing a strong model fit. Model 2 yielded satisfactory fit indices ($\chi 2 = 0.397$, $p = 1.000$; TLI = 1.068; CFI = 1.000; RMSEA = 0.000; SRMR = 0.012), suggesting that the hypothesized relationships between the latent variables and the observed data were well-supported. These fit statistics—notably the Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI), which exceeded the generally accepted threshold of 0.90—indicate that the model is robust and accurately represents the underlying structure of TPCEK. In addition, the Root Mean Square Error of Approximation (RMSEA) value of 0.000, along with the Standardized Root Mean Square Residual (SRMR) of 0.012, within acceptable ranges, further reinforcing the validity of the model. These indices suggest that the model fits the data well and captures the complexity and multidimensional nature of TPCEK as a construct. These results provide strong empirical support for the theoretical proposition that TPACK is a distinct form of knowledge shaped primarily by the hybrid components. In contrast, the core components serve as foundational knowledge bases.

The study of understanding TPACK is crucial for developing teachers' instructional abilities and addressing students' needs, particularly in an era where technology plays a significant role in education. The development of TPACK enables teachers to effectively integrate knowledge of technology, pedagogy, and subject matter, enhancing the quality of teaching and learning. This is particularly evident as students participate in selecting teaching methods through the TPACK framework. When teachers understand and utilize TPACK appropriately, they can better choose suitable instructional technologies that promote students' learning. Furthermore, training focused on developing TPACK is vital in increasing the effectiveness of technology use in the classroom. This approach responds to the needs of learners in the digital age by creating a learning environment that stimulates interest and fosters the skills necessary for education in the 21st century (Mishra & Koehler, 2006b; Niess, 2005).

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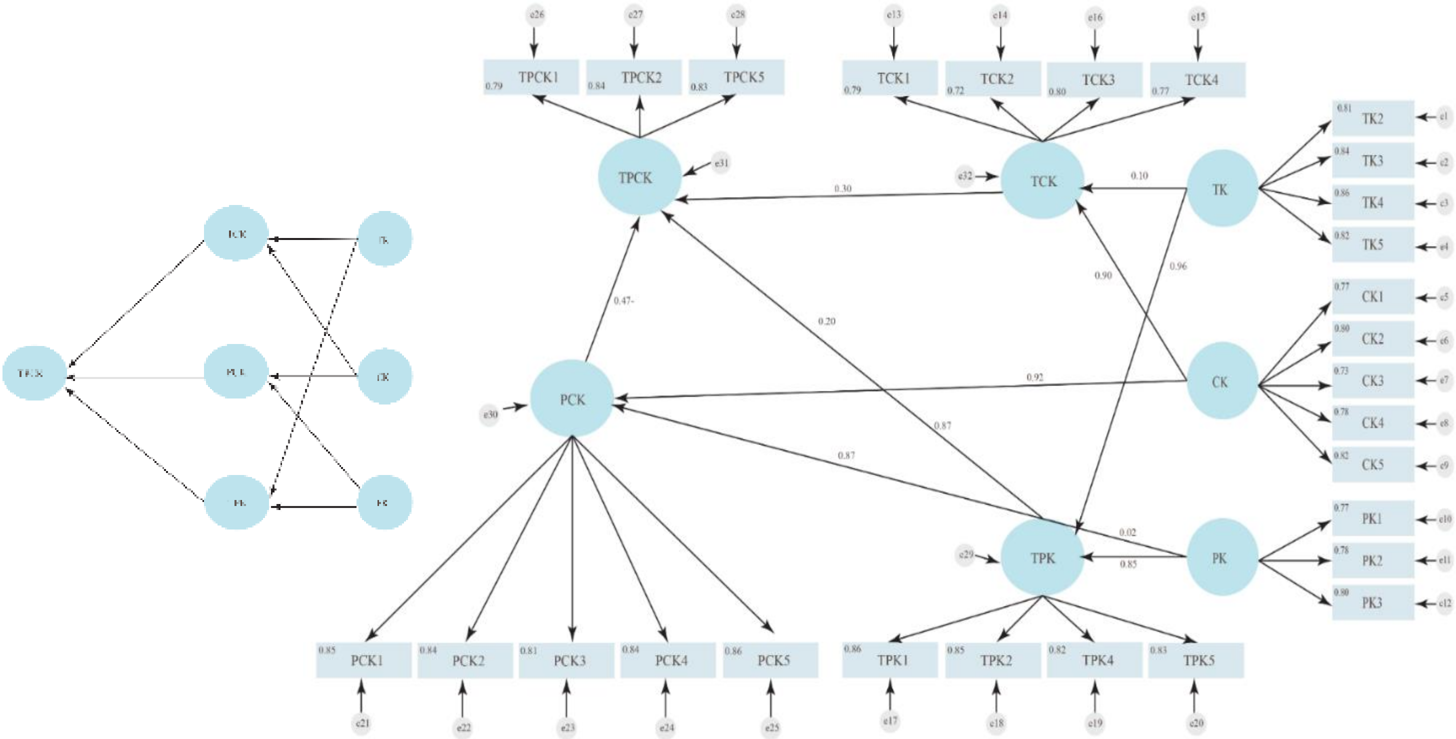

Figure 2 Structural equation model and hypothetical relationship model (inserted image).

The survey results highlighted students' preference for technology-integrated teaching methods, emphasizing the need to adapt instructional designs to enhance learner engagement. This preference indicates that digital tools and interactive learning environments can improve motivation, active participation, and student knowledge retention. As students become increasingly familiar with digital technologies, their expectations for more engaging, technology-enhanced learning experiences also rise.

Furthermore, these findings underscore educators' need to incorporate technology into their teaching practices strategically. Digital tools must be used to boost engagement and foster deeper understanding and meaningful learning. As technology evolves, teachers must have the skills to integrate new educational technologies effectively. This underscores the importance of professional development programs strengthening teachers' TPACK (Technological Pedagogical Content Knowledge) competencies. This study contributes to the role of technology in modern education by exploring students' preferences for technology-enhanced instruction. Its findings can inform curriculum developers, policymakers, and teacher training programs in creating instructional strategies that align with student expectations and promote more effective learning experiences.

4. Conclusion

This study investigated the instructional design needs of high school students in Surin province through the lens of the TPACK framework. The findings revealed that the final 28-item TPACK questionnaire is a reliable tool for assessing students' TPACK, demonstrating strong construct validity supported by both exploratory and confirmatory factor analyses. The exploratory factor analysis identified a seven-factor solution accounting for 71% of the total variance, with robust factor loadings indicating clear associations between items and their respective constructs. Furthermore, the confirmatory factor analysis confirmed the appropriateness of the model, yielding excellent fit indices, which validate the multidimensional nature of the TPACK framework. The survey results also highlighted students' preference for technology-integrated teaching methods, emphasizing the importance of adapting instructional designs to enhance learner engagement. These insights will be instrumental in developing effective teaching strategies that align with students' needs, ultimately fostering more engaging and effective educational experiences.

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