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Research Article

A Pilot Study of Attributing Factors for Pre-service Art Teachers' TPACK

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Abstract
This paper presents a pilot study conducted to refine research instruments for assessing Technological Pedagogical Content Knowledge (TPACK) among pre-service art teachers. The study utilized quantitative and qualitative methods, employing both Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) to evaluate the reliability and validity of the instruments. The pilot study informed critical adjustments in questionnaire design and interview procedures, ensuring the effectiveness of the tools for the main research.

Keywords: *Pilot study; EFA; CFA; Semi-Structure Interview; TPACK, Pre-Service Art Teachers*

1. Introduction

Pilot studies are integral to testing and refining research instruments on a smaller scale to identify and resolve potential issues (Fowler, 2021). These studies act as rehearsals for data collection, ensuring the practicality of the design. This paper reports a pilot study aimed at refining tools used to assess TPACK among pre-service art teachers, specifically focusing on improving questionnaire and interview formats.

Pilot studies allow researchers to identify and correct issues in research instruments and procedures before the main study begins (Creswell & Poth, 2022). Previous studies have demonstrated that pilot testing leads to more efficient data collection and better overall research design (Bryman, 2022). This study follows the established practice of using both quantitative and qualitative pilot testing methods.

Numerous studies have applied the TPACK framework to evaluate teachers' readiness to integrate technology into teaching (Brown & Moore, 2021). These studies primarily focus on general education teachers and those specializing in subjects such as science, mathematics, and language arts. Research in these areas has consistently shown that teachers' technological, pedagogical, and content knowledge are crucial for effective technology integration in the classroom.

However, limited research has focused on pre-service art teachers, who face unique challenges in integrating technology into the more subjective and creative aspects of art education. Art education often involves hands-on practices, and the technological tools required for teaching visual and performing arts differ significantly from those used in other subjects. Pre-service art teachers must learn not only how to use these tools but also how to integrate them effectively into creative pedagogical practices.

This study makes a novel contribution by specifically focusing on pre-service art teachers' use of the TPACK framework. It addresses a gap in the existing literature by exploring how these teachers develop the technological and pedagogical skills necessary to merge digital tools with traditional art instruction, ultimately providing insights into how art educators can better prepare for technology integration in their classrooms.

This research also highlights the need for more specialized training programs tailored to the unique requirements of art education, ensuring that pre-service art teachers are equipped with the necessary skills and knowledge to teach in digitally enriched environments. By focusing on this underexplored area, the study adds to the five factors affecting on pre-service teachers' TPACK level.

2. Methodology

Participants and Sampling

A random sampling method was used to select 102 pre-service art teachers from HST University. These participants spanned four grade levels, ensuring a diverse range of responses. Five incomplete questionnaires were removed, resulting in a 95.2% effective response rate, which was deemed sufficient for statistical analysis.

Data Collection

The study employed both quantitative (survey questionnaire) and qualitative (interviews) methods. The questionnaire consisted of 59 items based on the TPACK framework. Interviews were conducted to evaluate the open-ended responses for clarity and potential improvements. Prior to data collection, participants were informed about the study, and informed consent was obtained.

There are six key research questions for this study. These are:

1. What are the pre-service teachers' levels of TPACK knowledge?
2. To what extent do the following social-demographic factors affect pre-service art teachers' TPACK levels:
   a) gender
   b) grade of study
   c) type of institution
   d) duration of technology usage
   e) usage of the type of technology
   f) internship experience
3. Is there a significant difference in the pre-service teachers' levels of TPACK knowledge by gender, grade of study，type of institution，duration of technology usage，usage of the type of technology and internship experience？
4. To what extent do the human factors，professional identity，self-efficacy，self-knowledge affect pre-service art teachers' TPACK levels?
5. Is there a significant relationship between
   a) social factors and pre-service teachers' TPACK level?
   b) school environment and pre-service teachers' TPACK level?
   c) technical willingness and pre-service teachers' TPACK knowledge?
   d) national policy and pre-service teachers' TPACK knowledge?
   e) human factors and pre-service teachers' TPACK level?
6. To what extent do human factors moderate between social factors，technical willingness， national policy， school environment and pre-service teachers' TPACK level.
7. What are the pre-service teachers' perception of the following factors that affect their TPACK knowledge:
   a) social-demographic factors
   b) social factors
   c) school environment
   d) technical willingness
   e) national policy
   f) human factors

3. Data Analysis

The quantative data analysis employed two main analytical methods: exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). EFA was primarily used to identify potential dimensions and explore interrelationships among variables at the early stages of research (Field, 2021). In contrast, CFA, a more complex technique, was used to validate theoretical models or hypotheses by assessing the fit of these models through factor analysis (Kline, 2023).

According to recent literature, all the items in the TPACK framework questionnaire were analyzed using both EFA and CFA (Brown & Moore, 2021). The aim of this analysis was to reduce the number of variables, clarify the relationships between variables, validate the questionnaire, and investigate multicollinearity issues (Byrne, 2022).

3.1 Exploratory Factor Analysis (EFA)

In this study, the EFA was conducted in two parts. First, an EFA was performed on the TPACK levels to identify the underlying structure in the areas of technological, pedagogical, and content knowledge among pre-service teachers. Second, an EFA was conducted on the factors affecting TPACK levels to uncover the key factors influencing the development of TPACK in pre-service teachers. Through these two parts of EFA analysis, the study aims to gain a deeper understanding of the composition of TPACK and its influencing factors, providing a theoretical foundation for subsequent research.

EFA for TPACK Level

A factor analysis was conducted on the Technological Pedagogical Content Knowledge (TPACK) framework, analyzing 33 items from the second part of a questionnaire. In Table 3.1, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy for TPACK was 0.889, surpassing the threshold of 0.6 (Tabachnick & Fidell, 2007). The KMO measure ranges from 0 to 1, reflecting the degree of partial correlation among variables.

A higher KMO value indicates more common variance shared among the observed variables. According to Kaiser (1974), a KMO value between 0.60 to 0.69 is considered mediocre, between 0.70 to 0.79 is moderate, and between 0.80 to 0.89 is great. The KMO value suggests that the sample size is sufficient for factor analysis. The Bartlett's test of sphericity was statistically significant (chi-square = 3239.207, $p < .001$), indicating that the variables in the scale are related and highly suitable for factor analysis (Loewen & Gonulal, 2015).

Table 3.1

KMO and Bartletts Test for TPACK Level

Kaiser-Meyer-Olkin	Measure of sampling Adequacy	0.889
Bartletts Test of Sphericity	Approx. Chi-Square	
	df	3239.207
	Sig	528
		.000

In Table 3.2, a preliminary analysis of the eigenvalues of all factors in the data revealed that four factors had eigenvalues greater than Kaiser's criterion of 1. According to these data, the eigenvalues of the first five factors were all greater than 1, indicating they are all worth considering in the analysis. Following Kaiser's criterion, factors with eigenvalues greater than 1 are generally recommended to be retained. Thus, these factors together explain approximately 70% of the variance, signifying their significant role in the variability of the dataset.

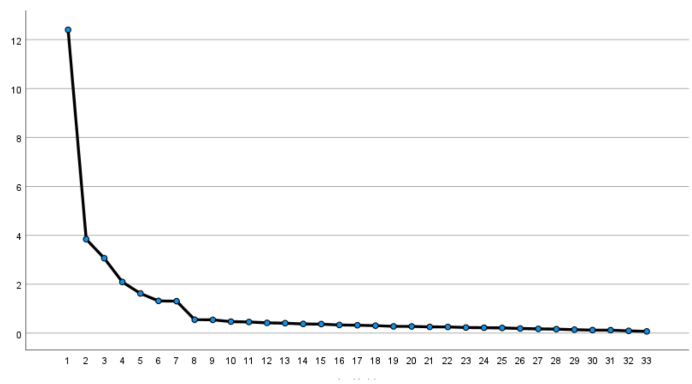
Table 3.2

Total Variance Explained for TPACK Level

Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
12.407	37.597	37.597	12.407	37.597	37.597	5.455	16.532	16.532
3.842	11.644	49.24	3.842	11.644	49.24	5.441	16.489	33.02
3.062	9.279	58.519	3.062	9.279	58.519	3.932	11.914	44.934
2.091	6.337	64.856	2.091	6.337	64.856	3.833	11.615	56.549
1.622	4.915	69.772	1.622	4.915	69.772	2.372	7.186	63.735

Figure 3.1

Scree Plot for TPACK Level



In Figure 3.1, the Scree Plot for TPACK Level, the eigenvalue of the first factor is significantly high, with a sharp decline following the first factor. After the second factor, the decrease in eigenvalues tends to level off but still shows a declining trend. According to the scree plot, after the fifth factor, the decline in eigenvalues becomes very gradual, nearly parallel to the horizontal axis. Based on this plot, we choose to retain the first five factors, as the contribution of subsequent factors to the total variance is relatively small. This decision should be made in conjunction with the Kaiser criterion (factors with eigenvalues greater than 1 should be retained) and consideration of the interpretability of the factors.

After the second rotation, as shown in Table 3.3, all 33 items were satisfactorily distributed across 7 components, with each item having loadings higher than 0.6. Thus, the sub-structures in the factor analysis were labeled as (1) TK, (2) CK, (3) PK, (4) PCK, (5) TPK, (6) TCK, and (7) TPACK. Table 3.3 displayed the rotated component matrix.

Table 3.3
Rotated Component Matrix for TPACK Level

Rotated Component Matrixa							
	Component						
	1	2	3	4	5	6	7
TK1	0.837						
TK2	0.807						
TK3	0.836						
TK4	0.796						
TK5	0.811						
TK6	0.814						
TK7	0.792						
CK1							0.772
CK2							0.801
CK3							0.791
PK1		0.783					
PK2		0.809					
PK3		0.855					
PK4		0.863					
PK5		0.753					
PK6		0.8					
PK7		0.82					
PCK1					0.82		
PCK2					0.813		
PCK3					0.756		
TPK1			0.841				
TPK2			0.784				
TPK3			0.827				
TPK4			0.861				
TPK5			0.803				
TCK1						0.813	
TCK2						0.818	
TCK3						0.784	
TPACK1				0.745			
TPACK2				0.789			
TPACK3				0.814			
TPACK4				0.826			
TPACK5				0.766			

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization. a. Rotation converged in 5 iterations.

As shown in Table 3.4, the construction of TPACK features a seven-factor structure, which aligns with the literature on achieving objectives. The results of the Exploratory Factor Analysis (EFA) for TPACK revealed seven components, with 33 items effectively loaded across these components. Consequently, the seven components of the TPACK scale are labeled as TK, CK, PK, TPK, TCK, PCK, and TPACK.

Table 3.4
Final EFA Result for TPACK Level

Item		Component						
		1	2	3	4	5	6	7
TK1	I know how to solve the technical problems in teaching (including computer network connection， electronic board operation， PPT play projection， etc.)	0.837						
TK2	I can learn educational technology easily.	0.807						
TK3	I can always learn new information technology	0.836						
TK4	I have applied the educational technology I learned many times in teaching activities	0.796						
TK5	I know a lot about many different types of educational technology.	0.811						
TK6	I have some methods and abilities to apply various educational technologies.	0.814						
TK7	I have many opportunities to use various types of educational technology in my study.	0.792						
CK1	I can fully understand and master the discipline knowledge related to the professional field of visual art.							0.772
CK2	I think about some current puzzles with the help of discipline training thinking.							0.801
CK3	I use different methods to improve my mastery of subject knowledge.							0.791
PK1	I know how to correctly evaluate student performance in teaching activities.		0.783					
PK2	I can adjust teaching according to student learning situation in teaching activities.		0.809					
PK3	I can use different teaching styles for different students in teaching activities.		0.855					
PK4	I can use different ways to evaluate student learning in teaching activities.		0.863					
PK5	I can use many different types of methods in teaching activities (for example， group discussion， etc.) to complete the teaching work		0.753					
PK6	I can pay attention to and understand student understanding of problems and error prone points in the learning process		0.8					
PK7	I know how to maintain classroom discipline and carry out learning activities in teaching activities		0.82					
PCK1	I understand that effective methods can be used in teaching activities to help students master subject knowledge and establish corresponding subject thinking system.					0.82		
PCK2	I can use various teaching methods to match the corresponding subject topics.					0.813		
PCK3	I can adopt appropriate teaching methods to solve the confusion encountered by students in the process of learning.					0.756		

TPK1	I can apply relevant teaching techniques to different teaching methods in teaching activities.	0.841		
TPK2	I can apply relevant teaching techniques in teaching activities based on student learning situation	0.784		
TPK3	I understand how teaching technology affects teaching methods.	0.827		
TPK4	I can think critically about how to use educational technology in classroom teaching.	0.861		
TPK5	In educational practice， according to different types of teaching activities， I can appropriately improve the use of teaching technology	0.803		
TCK1	I know some teaching techniques that can promote students to learn and understand the content of subject knowledge			0.813
TCK2	I can teach subject content knowledge with the help of appropriate information technology in teaching activities			0.818
TCK3	I can use appropriate information technology in teaching activities to teach students relevant concepts to promote student understanding.			0.784
TPACK1	I can properly integrate subject content， educational technology and teaching methods in educational practice		0.745	
TPACK2	I can integrate subject knowledge， educational technology knowledge and teaching method knowledge into an integrated knowledge		0.789	
TPACK3	I can consolidate student mastery of the subject knowledge I teach with the help of information technology in educational practice		0.814	
TPACK4	I can use some information technology in teaching activities to improve teaching methods and help enrich student knowledge content		0.826	
TPACK5	I can provide some support for other normal students in subject knowledge teaching， applied teaching technology and teaching methods， and can play a certain exemplary and leading role.		0.766	

EFA for Factors Affecting TPACK

Table 3.5 shows that the KMO value is 0.937, which is very close to 1, indicating a high degree of commonality among variables, making it suitable for factor analysis. The significance result is close to 0, indicating that we can reject the null hypothesis that the correlation matrix is an identity matrix, i.e., there is interdependence among the data, making it suitable for factor analysis.

Table 3.5
KMO and Bartletts Test for Factors Affecting TPACK

Kaiser-Meyer-Olkin	Measure of sampling Adequacy	0.937
Bartletts Test of Sphericity	Approx. Chi-Square	2596.678
	df	325
	Sig	.000

A preliminary analysis of the eigenvalues of all factors in the data revealed that four factors had eigenvalues greater than Kaiser's threshold of 1. In Table 3.6, we can see that initial eigenvalues indicate that five factors were extracted, but only the first four factors have eigenvalues greater than 1. The first factor's eigenvalue is 12.59, accounting for 48.422% of the total variance, with a cumulative variance of 48.422%. The second factor's eigenvalue is 2.872, accounting for 11.046% of the total variance, with the cumulative variance for two factors at 59.468%.

The third factor's eigenvalue is 1.912, accounting for 7.353% of the total variance, with the cumulative variance for three factors at 66.821%. The fourth factor's eigenvalue is 1.58, accounting for 6.076% of the total variance, bringing the cumulative variance for four factors to 72.897%. According to the table information, this factor analysis revealed four significant factors, considered substantial according to Kaiser's criterion, and explained a majority of the variance in the data.

Table 3. 6
Total Variance Explained for Factors Affecting

Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
12.59	48.422	48.422	12.59	48.422	48.422	6.096	23.447	23.447
2.872	11.046	59.468	2.872	11.046	59.468	5.21	20.039	43.486
1.912	7.353	66.821	1.912	7.353	66.821	3.323	12.779	56.265
1.58	6.076	72.897	1.58	6.076	72.897	3.19	12.271	68.536

The rotated component matrix shown in Table 3.7 is part of the factor analysis used to determine the loadings of each item (variable or question) on the various factors. Loadings measure the degree to which each item contributes to each factor. Typically, we hope that each item has high loadings primarily on only one factor to clearly distinguish between different factors. In factor analysis, if an item has high loadings on two or more factors, it could interfere with the distinction between factors, meaning it contributes significantly to the variance across multiple factors. As Field (2013) suggested, if an item has too high cross-loadings between different factors, it should be considered for removal from the analysis.

Table 3.7
Rotated Component Matrix for Factors Affecting TPACK

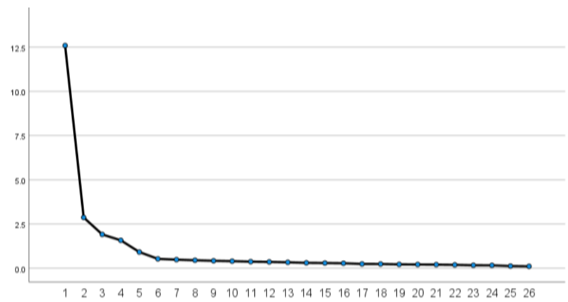
Rotated Component Matrixa	Component			
	1	2	3	4
HF1	0.812			
HF2	0.796			
HF3	0.824			
HF4	0.814			
HF5	0.856			
HF6	0.802			
HF7	0.761			
HF8	0.749			
SE1		0.815		
SE2		0.726		

SE3		0.804			
SE4		0.815			
SE5		0.75			
SE6		0.759			
SE7		0.812			
SF1			0.791		
SF2			0.81		
SF3			0.84		
SF4			0.762		
TW1				0.733	
TW2				0.795	
TW3				0.796	
TW4				0.789	
NP1					
NP2					
NP3					

Note. Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization. a. Rotation converged in 5 iterations.

After the first rotation, the items National Policy1, National Policy2, and National Policy3 had very similar loadings across different factors, indicating these items may not be suitable for clearly defining any one factor. Therefore, following this guidance, choosing to remove these three items is justified. A second analysis conducted after the removal of these items extracted four factors, suggesting that the contribution of the remaining items to the factors became clearer after the problematic items were removed. This process helps to improve the clarity and interpretability of the factor solution.

Figure 3.2
Scree Plot for Factors Affecting TPACK



In Figure 3.2, the Scree Plot for Factors Affecting TPACK, the first factor has a very high eigenvalue, significantly surpassing the others, indicating it captures most of the variability in the data. The eigenvalues drop sharply after the first factor, suggesting the second factor and subsequent factors explain less variability in the data. After the fourth factor, the decline in eigenvalues becomes very gradual, almost forming a horizontal line. This indicates that the fifth factor and beyond contribute little to explaining the variability in the data. Based on this scree plot, a reasonable choice might be to retain the first four factors. These four factors appear before the elbow in the curve of descending eigenvalues, and after this point, the reduction in eigenvalues slows down significantly. In this case, the first four factors would be retained because their eigenvalues are greater than 1, and they occupy a prominent position in the plot.

After the second rotation, all 23 items were satisfactorily distributed across 4 components, with each item having loadings higher than 0.6. Without the mix of items from the original three components of the National Policy structure, the sub-structures in the factor analysis were labeled as (1) Human Factors, (2) School Environment, (3) Social Factors, and (4) Technical Willingness. Table 3.24 displayed the rotated component matrix after the second rotation.

The results from the rotated component matrix in Table 3.26 show that all 23 items were adequately classified into 4 components. The results indicate that the first factor consists of 8 items, with loadings ranging from 0.755 to 0.829, named "Human Factors". The second factor consists of 7 items, with loadings ranging from 0.761 to 0.823, termed "Social Environment". The third factor has 4 items, with loadings ranging from 0.779 to 0.828, called "Social Factors". The fourth factor consists of 4 items, with loadings ranging from 0.74 to 0.805, named "Technical Willingness". Finally, the ultimate instrument included 23 items covering four components and was subjected to further investigation.

As it show in Table 3.8, the EFA results indicate that Factors Affecting TPACK consists of 23 items, comprising 4 sub-structures: (1) Human Factors, (2) School Environment, (3) Social Factors, and (4) Technical Willingness. Therefore, the four components of the Factors Affecting TPACK instrument are labeled as (1) Human Factors, (2) School Environment, (3) Social Factors, and (4) Technical Willingness.

Table 3.8
Final EFA Result for Factors Affecting TPACK

	Item	Component			
		1	2	3	4
HF1	I am confident to undertake the course of combining art knowledge，technology and teaching.	0.818			
HF2	As long as I work hard enough，I know I can have a positive impact on students academic performance.	0.806			
HF3	I am confident to assist students in learning technology.	0.829			
HF4	I am confident to conduct classroom teaching with the use of information technology.	0.818			
HF5	I am confident to use information technology or software to design challenging tasks to broaden students critical thinking.	0.86			
HF6	I am confident that by integrating information technology into the teaching of Art，I will be able to greatly improve the delivery of the course.	0.809			
HF7	I am able to increase my knowledge of the subject with the incorporation of technology in the curriculum.	0.765			
HF8	I think the teaching profession gives me the opportunity to realize my own values.	0.755			
SE1	My school provides me with many opportunities for educational practice and classroom teaching training.		0.814		
SE2	My school provides sufficient technical hardware to ensure the implementation of technology in teaching.		0.725		
SE3	My school provides sufficient technical software to support the integration of technology in a course.		0.812		
SE4	My school provides technical support to help solve any technical problems faced during the delivery of technology integrated courses.		0.823		
SE5	My school encourages actively application and exploration of information technology in teaching.		0.766		
SE6	My school constantly invests in purchasing of information technology equipment.		0.761		
SE7	My school constantly upgrades the software and hardware to enhance the incorporation of information technology in teaching and learning.		0.818		
SF1	I think teachers have a high social status.			0.821	
SF2	Mastering information technology can greatly improve my social competitiveness.			0.806	
SF3	My companions are actively engaged in information teaching and learning.			0.828	
SF4	My family encourages me to study information technology.			0.779	
TW1	Teaching with technology is easy for me.				0.74
TW2	Using technology enables me to teach faster.				0.805
TW3	When I become a teacher，I intend to use technology in teaching.				0.803
TW4	I am very interested in the application of technology in teaching.				0.793

3.2 Confirmatory Factor Analysis (CFA)

Bollen and Pearl (2020) noted that Confirmatory Factor Analysis (CFA) was regarded as a subset of SEM, allowing the evaluation of pre-established theories or models. In CFA, particular attention was given to factor loadings and fit indices.

CFA analysis was conducted using SPSS AMOS (version 26) to determine the reliability and validity of the instruments. Brown (2020) suggested that items with low factor loadings should be removed and noted that factor loadings above 0.5 are suitable for newly developed items, while a higher threshold of 0.6 is recommended for established items. Therefore, in this study, the factor loadings for items should be above 0.6.

After the initial run of the measurement models for the questionnaires, AMOS checked multiple indicators such as factor loadings and fit indices. Areas for modifications were identified, and unnecessary items were removed to ensure that the model fit indices met the required level of acceptability.

Figure 3.3
Confirmatory Factor Model for Pre-service teacher's TPACK Level

Figure3.3 presents a Confirmatory Factor Model (CFA) designed to assess pre-service teachers' TPACK levels. The main latent variables in the model include TK, CK, PK, PCK, TPK, TCK, TPACK. These observed variables represent actual measurable data that reflect the specific manifestations of the latent variables. The p-values and fit indices in the model are shown in Table 3.24.

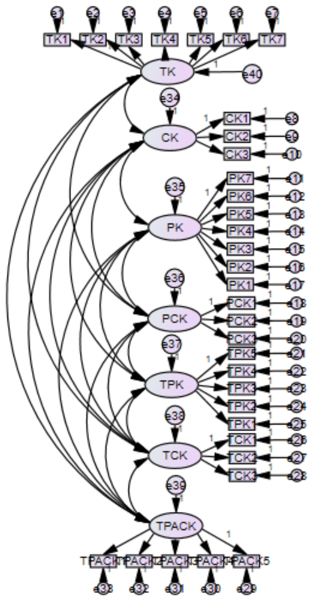


Table 3.9 presents the fit indices of a Structural Equation Model (SEM) used to assess how well the model fits the data. The indices show that the model meets or exceeds the required standards, indicating a good fit. The key indices like GFI, CFI, NFI, TLI, IFI, and AGFI all exceed the standard value of 0.9, indicating an excellent model fit. The RMSEA and RMR values are 0.000 and 0.040, respectively, both lower than the thresholds of 0.10 and 0.05, indicating minimal errors in the model. Other parsimony indices like PGFI, PNFI, and PCFI are also within reasonable ranges. Overall, the model demonstrates high fit quality and is well-suited to explaining the data.

Table 3.9
Final CFA Result for Pre-Service Teachers' TPACK Level

Model Fit Indices										
Common indices	χ2	*df*	*p*	χ2/*df*	GFI	RMSEA	RMR	CFI	NFI	NNFI
Criterion	-	-	>0.05	<3	>0.9	<0.10	<0.05	>0.9	>0.9	>0.9
Value	441.031	474	0.859	0.930	0.934	0.000	0.040	1.004	0.953	1.004
Other indices	TLI	AGFI	IFI	PGFI	PNFI	PCFI	SRMR			

Model Fit Indices										
Common indices	$\chi2$	*df*	*p*	$\chi2/df$	GFI	RMSEA	RMR	CFI	NFI	NNFI
Criterion	-	-	>0.05	<3	>0.9	<0.10	<0.05	>0.9	>0.9	>0.9
Criterion	>0.9	>0.9	>0.9	>0.5	>0.5	>0.5	<0.1			
Value	1.004	0.922	1.004	0.789	0.855	0.901	0.025			
Note：Default Model: $\chi2(528) = 9338.214$, $p = 1.000$										

4. Results

The pilot study provided critical insights into the clarity and effectiveness of the research tools. The identified issues in the questionnaire and interview design were effectively addressed, resulting in improved instruments. By employing Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA), the study ensured that the tools were reliable and suitable for the main research project. The results underscore the importance of pilot testing in refining research methodologies.

Based on the results of the semi-structured interviews and the quantitative analysis of the TPACK framework, several key conclusions can be drawn:

The study indicates that pre-service art teachers possess varying levels of TPACK knowledge, with some areas showing stronger proficiency while others are relatively weak. The semi-structured interviews revealed that although participants had a solid foundation in Content Knowledge (CK) and Pedagogical Knowledge (PK), they encountered significant challenges in integrating Technological Knowledge (TK) into their teaching practices. Many participants expressed difficulties in seamlessly combining these three dimensions (CK, PK, and TK) in their teaching strategies, which is essential for developing robust TPACK skills.

Quantitative analysis showed that several socio-demographic factors significantly affected pre-service teachers' TPACK levels:

Gender: There were no significant differences in TPACK levels based on gender. Both male and female participants demonstrated similar challenges and strengths in technological integration.

Year of Study: Participants in higher years of study, particularly those with more internship experience, exhibited higher TPACK levels, especially in the application of pedagogical knowledge (PK) and the use of technology in the classroom.

Type of Institution: The type of school significantly influenced TPACK levels. Students from private art institutions had more exposure to advanced technology, leading to higher scores in Technological Content Knowledge (TCK) and Technological Pedagogical Knowledge (TPK) compared to students from public institutions.

Technology Usage: Participants who had used educational technology for a longer period and those who had engaged with more advanced types of technology (such as digital media tools and online platforms) demonstrated higher TPACK competency.

The interviews further emphasized the importance of internship experience in enhancing pre-service teachers’ ability to integrate technology with pedagogy and content. Teachers with more hands-on experience in real classroom settings were more confident in using technology to enhance student learning. Internships provided opportunities to experiment with various tools and methods, fostering a deeper understanding of how to blend technology with teaching practices.

The analysis also confirmed significant relationships between social factors, the school environment, and TPACK levels. Supportive school environments that provided access to technological resources, as well as national policies promoting technology integration, played a crucial role in enhancing pre-service teachers' technological skills. In contrast, participants who lacked institutional support or access to modern technology faced greater challenges in developing their TPACK.

The semi-structured interviews highlighted the role of human factors, such as collaboration with peers and mentors, in mediating the development of TPACK. Participants who worked closely with colleagues in technology-driven projects were able to advance their TPACK levels more effectively. Additionally, those with a high level of technical willingness—a positive attitude towards learning and using new technologies—were more likely to successfully integrate technology into their teaching practices.

Both qualitative and quantitative data indicated that while pre-service teachers were making strides in TPACK development, there is still a need for more structured support in developing TPACK. Participants highlighted the need for more targeted training programs, practical workshops, and ongoing mentorship to help them integrate technology more effectively in classroom environments.

5. Conclusion

In summary, this study shows that pre-service teachers' TPACK levels are influenced by a combination of socio-demographic factors, institutional support, technical willingness, and internship experience. While there is evidence of progress in developing TPACK, challenges remain in integrating technology into pedagogy and content. The findings suggest that enhanced institutional support, policy initiatives, and targeted professional development can significantly improve pre-service teachers' TPACK competencies, ultimately leading to more effective teaching practices in technology-rich educational environments.

6. References

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