Journal of Infrastructure, Policy and Development 2024, 8(14), 9058.
https://doi.org/10.24294/jipd9058

Article

Construction and application research of intelligent classroom teaching system based on TPACK level of normal students in Chinese colleges and universities

Yingdi Lu[1,2,*], Mohd Nihra Haruzuan Bin Mohamad Said[2]

[1] Wenzhou Medical University, Wenzhou 325000, China
[2] Faculty of Educational Sciences and Technology, Universiti Teknologi Malaysia, Skudai 81310, Malaysia
*** Corresponding author:** Yingdi Lu, luyingdi@graduate.utm.my

CITATION

Lu Y, Said MNHBM. (2024). Construction and application research of intelligent classroom teaching system based on TPACK level of normal students in Chinese colleges and universities. Journal of Infrastructure, Policy and Development. 8(14): 9058. https://doi.org/10.24294/jipd9058

ARTICLE INFO

Received: 10 September 2024
Accepted: 25 October 2024
Available online: 19 November 2024

COPYRIGHT

Copyright © 2024 by author(s). *Journal of Infrastructure, Policy and Development* is published by EnPress Publisher, LLC. This work is licensed under the Creative Commons Attribution (CC BY) license. https://creativecommons.org/licenses/by/4.0/

Abstract: Technical Pedagogical Content Knowledge (TPACK) encompasses teachers' understanding of the intricate interplay among technology, pedagogy, and subject matter expertise, serving as the essential knowledge base for integrating technology into subject-specific instruction. Over the decade, advancements in information technology have led to the consistent application of the TPACK framework within studies on instructional technology and technology-enhanced learning, significantly advancing the evolution of contemporary teacher education in technology integration. In this paper, we utilize the Teaching and Learning Knowledge of Subjects Based on Integrated Technology (TPACK) framework to administer a questionnaire survey to teacher trainees at Chinese colleges and universities. This survey aims to evaluate the current status of their integrated technology-based subject teaching and learning knowledge. Based on the research findings, we propose strategies aimed at enhancing the educational technology integration knowledge of students pursuing integrated technology courses in colleges and universities. Furthermore, we integrate the smart classroom setting to develop a comprehensive TPACK-integrated model teaching framework. Our final objective is to offer valuable references for the progress of modern teaching skills among education students in higher education institutions.

Keywords: TPACK; integration model; higher education; smart classroom; technology integration

1. Introduction

The advent of intelligent technology, as highlighted by Goddard et al. (1997), represents a significant shift in human society, profoundly impacting both lifestyles and learning paradigms. Currently, the seamless integration of intelligent technology with education and teaching constitutes a pivotal trend in contemporary educational landscapes. Numerous educational investigations have attested to the efficacy of intelligent technologies in facilitating instruction, as noted by Herold (2016). Additionally, some scholars argue that intelligent technology has transcended its role as a mere adjunct to traditional teaching methods. Instead, it has emerged as a pivotal element within the intelligent teaching paradigm, playing a vital role in augmenting teachers' instructional competencies and students' learning abilities (Seufert et al., 2021). Currently, the question of the appropriate knowledge structure for teachers has become a focal point in educational research. Serving as the cornerstone of teachers' professional growth, the TPACK framework is considered the foundation for educators to effectively integrate technology into teaching in the digital age. It offers trainees direction on how to embed technology into classroom instruction (Koehler et al., 2014). Over the past decade, advancements in information technology have led to the extensive application of the TPACK framework in research concerning instructional technology and technology-enhanced learning, significantly advancing the development of educational technology among educators (Hilton, 2016).

Nonetheless, the majority of existing research on the Subject Teaching Knowledge with Integrated Technology (TPACK) primarily emphasizes theoretical advancements, with insufficient investigations into its present state. Furthermore, in the realm of smart classroom practice, the detachment between intelligent technology and classroom implementation persists due to teachers' limited understanding of smart technology, design flaws in smart technology's human-computer interaction, and other factors. Consequently, the thorough integration of intelligent technology with curricula remains inadequate. Based on the theoretical framework of TPACK, this research delves into the modern teaching capabilities of teacher trainees in Chinese universities in the information technology era. It establishes a teaching system that incorporates the TPACK model within smart classrooms. The aim is to offer insightful perspectives for enhancing the contemporary teaching skills of teacher trainees in Chinese higher education institutions.

2. Literature review

Artificial intelligence (AI), an emerging field within computer science, has significantly transformed numerous domains (Lin et al., 2021). In the context of education, AI technology has likewise had a profound impact on educators and learners, particularly through the deployment of intelligent tutoring systems and automated assessment tools (Montebello, 2018).

The progression into the era of artificial intelligence and the evolution of educational technologies will undoubtedly have a profound impact on both the theoretical and practical dimensions of teachers' professional development, presenting novel challenges for educators in the intelligent age. It is imperative to equip teachers with technological expertise to meet the requirements of the "new cohort of digital learners," leveraging the capabilities of information technology to diversify and enrich learning pathways, ultimately improving the effectiveness of both "teaching" and "learning" experiences (Hsu, 2015). Balyer and fellow researchers have emphasized the vital significance of cultivating digital literacy skills among educators within the framework of artificial intelligence, a process that is closely intertwined with teacher education and university research initiatives (Balyer et al., 2018). Various investigations have underscored the importance of comprehensive teacher training, spanning both initial and continuous professional development programs, for enabling educators to effectively integrate and sustainably leverage technology in their teaching practices (Becta, 2004; Davis et al., 2009; Hennessy et al., 2007; Jimoyiannis and Komis, 2007). Therefore, given the numerous transformations in the educational landscape, it is crucial to investigate the teacher knowledge framework that is compatible with the intelligent teaching environment and subsequently adjust the teacher training program accordingly.

In the 21st century, scholars have increasingly recognized the pivotal role of technology in shaping teachers' knowledge structures, emphasizing the significance of student-centered values in the process, leading to the development of a complex and interconnected knowledge system framework. Within the diverse perspectives on teacher knowledge research, Technological Pedagogical and Content Knowledge (TPACK) emerges as a prominent framework (Ching, 2013; Voogt et al., 2013). Introduced by American scholars Koehler and Mishra in 2005, TPACK builds upon Shulman's model of Pedagogical Content Knowledge (PCK) (Koehler et al., 2005). The schematic representation of TPACK, as depicted by Weien, clearly illustrates that the framework comprises three fundamental components: content knowledge (CK), pedagogical knowledge (PK) and technological knowledge (TK). Moreover, it encompasses four additional composite elements: pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and ultimately, TPACK itself, which emerge from the interactive dynamics among the aforementioned core elements. Collectively, these seven aspects constitute a holistic TPACK framework, as illustrated in **Figure 1**.

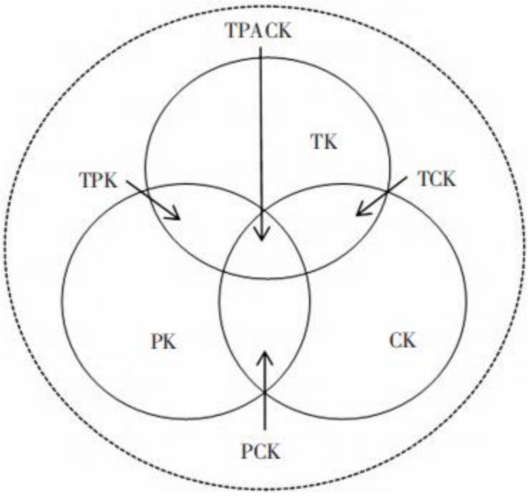

Figure 1. Subject teaching knowledge model of integrated technology.

TPACK represents a multifaceted form of teacher expertise that entails the seamless integration of content knowledge, pedagogical insight, and technological skill (Cox, 2008; Koehler and Mishra, 2008). This framework clarifies the role of educators and their comprehension of leveraging information technology to enhance the teaching of particular subjects (Koehler and Mishra, 2008). TPACK serves not only as a comprehensive knowledge base for teachers to align subject matter and pedagogical approaches with technology but also as a crucial foundation for educators to deliver subject instruction using integrated technological resources (Mishra and Koehler, 2006). Technological Knowledge, encompasses a broad range of technology-related understanding, including teachers' capacity for acquiring new technologies and the practical competencies needed for implementing specific technologies in real-world scenarios, among others. Content Knowledge, pertains to the expertise in the subject matter being instructed. Pedagogical Knowledge, encompasses all facets of pedagogy. Pehe instruction of subject matter content through pedagogical approaches, representdagogical Content Knowledge, represents the specialized understanding that teachers must possess concerning the subject matter they teach, encompassing facts, concepts, principles, and the like, as well as the expertise required to transform subject matter knowledge into formats that are readily comprehensible by students. The integration of subject matter knowledge with technology, involves the understanding of the interplay between technology and subject matter content, including the application of diverse technologies to subject matter. The integration of pedagogical knowledge with technology, pertains to the expertise in employing suitable technological tools to execute pedagogical strategies. The integration of subject matter pedagogical knowledge with technology, known as TPACK, involves the application of technology to ting a reintegration of the three integrated components: PCK, TCK, and TPK. While the TPACK framework was officially introduced in the 21st century and delineates the distinctive knowledge necessary for "effective technology-infused instruction," it has emerged as a crucial tool for fostering technology-enabled learning (Brantley-Dias et al., 2013) and has gained significance as a perspective through which to investigate teachers' knowledge configurations.

The smart classroom, leveraging advanced artificial intelligence technology, represents a profound integration of information technology with educational methodologies. Through the application of AI-powered perception technology, learning analytics, and emotional computing, a sophisticated educational paradigm has emerged, heralding the advent of smart teaching in academia. This transformation is rooted in IBM's introduction of the "Smart Planet" concept in 2008, followed by the implementation of the "Smart China" strategy in 2009 (Palmisano, 2008). In recent times, terms like smart classrooms, intelligent teaching models, smart educational environments, Yuketang, Internet Plus, and digital classrooms have garnered significant attention in academic circles. Currently, research on intelligent classroom teaching models primarily revolves around reassessing traditional classroom instruction, prioritizing collaborative student learning, amalgamating diverse learning approaches, transcending the constraints of conventional classroom temporal and spatial boundaries, and fostering adaptable and multifaceted intelligent teaching paradigms. For example, Sam Van Horne introduced the TILE flipped classroom model in smart classrooms by leveraging relevant intelligent technologies, emphasizing transformation, interaction, engagement, and immersion in learning, resulting in notable improvements in classroom interactivity (Horne et al., 2014). Agnes Kukulska-Hulme additionally observed that smart classrooms can positively influence students' personalized learning and development to a certain degree (Kukulska-Hulme, 2018). In comparison to traditional classrooms, smart classrooms exhibit significant distinctions, necessitating innovative teaching methods and learning formats to fully exploit their capabilities and facilitate effective and seamless learning experiences for students. Research on smart classrooms provides valuable insights for the comprehensive integration of information technology with subject-specific teaching, and serves as the theoretical basis for this paper in establishing an educational system centered on the TPACK integration model within the context of smart classrooms.

3. Research methodology

This research employed a mixed research method that combines quantitative and qualitative approaches to analyze the TPACK levels of teacher trainees in higher education institutions.

3.1. Sample selection and data collection

The data for this study were gathered between September and October 2023. Given that third- and fourth-year normal education students possess systematic training and a foundational knowledge base, the research sample included these highly developed teacher trainees from various colleges and universities. Participants were selected using stratified random sampling across first, second, and third-tier institutions, and questionnaires were subsequently administered. A total of 247 questionnaires were distributed, resulting in 239 valid responses, which amounts to an effective response rate of 96.7%.

3.2. Questionnaires

The questionnaire for this study was structured into two parts. The initial section aimed to gather demographic information from the respondents. The second section, known as the Technology Integration Subject Teaching Knowledge Scale for Teacher Trainees, was designed to assess the TPACK levels of teacher trainees in Chinese colleges and universities.The research utilized a revised version of the Subject Teaching Knowledge Scale for Teacher Trainees Integrating Technology, which was initially developed by Schmidt and tailored to fit the study's objectives (Schmid et al., 2020). Initially, a panel comprising three educational technologists and an English language teaching specialist translated the original questionnaire from English to Chinese, making necessary adaptations to align with the educational context in China. This was followed by a back-translation into English by another team consisting of three educational technologists and an English language teaching expert. Subsequently, six researchers convened to resolve any discrepancies in the translations and undertake a second revision of the Chinese questionnaire. Additionally, we sought input from three education experts and five pre-service teachers during the design and compilation phase. Based on their feedback, further refinements were made to ensure the questionnaire met the study's requirements. Ultimately, a preliminary questionnaire with 41 items was developed, each rated on a standardized 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

3.3. Semi-structured interviews

In order to explore more deeply the understanding of TPACK, its application in practical teaching, and the challenges and difficulties faced by teacher trainees in higher education, this study designed semi-structured interviews. During the interviews, we invited 10 teacher trainees from different disciplinary backgrounds who were at different stages of study, including sophomores, juniors and seniors. The interviews mainly covered the following aspects:

1) Understanding of the TPACK concept and its application in teaching practice;
2) Difficulties and challenges encountered in integrating technology for teaching subjects;

3) Assessment of the difference in effectiveness between the TPACK model of teaching and traditional teaching methods
4) The needs and expectations for improving the level of TPACK;
5) Perceptions of the smart classroom;
6) Evaluation of the existing education system and training resources.
7) Expectations and suggestions for the future development of TPACK.

By posing these interview questions, the researcher acquired a deeper comprehension of the teacher trainees' grasp and implementation of TPACK, alongside the obstacles they might face while teaching in a smart classroom setting. The insights gained serve as a crucial reference for the subsequent establishment and refinement of the TPACK integration model's teaching system within the context of smart classrooms.

4. Results and discussion

4.1. Reliability and validity of TPACK dimensions for normal college students

Table 1. Measure and index results of TPACK variables of normal students in colleges and universities.

Variable	Child variable	Item	Factor load							α	CR	AVE
			1	2	3	4	5	6	7			
PCK	PCK5	I possess the capability to address errors committed by students in the academic subjects that I instruct.	0.76							0.91	0.90	0.62
	PCK3	I understand how to reinforce students' mastery of instructional knowledge through the assignment of exercises.	0.75									
	PCK4	I possess the expertise to evaluate students' learning progress.	0.71									
	PCK6	In the subjects I instruct, I am capable of addressing the challenging and crucial issues faced by my students.	0.71									
	PCK1	I possess the ability to select efficient instructional strategies to direct students in their learning and cognitive processes.	0.66									
	PCK2	I am skilled at fostering deep reflection among students through the creation of suitable assignments.	0.65									
PK	PK4	I employed diverse methods to assess my students' learning outcomes.		0.77						0.92	0.92	0.67
	PK2	I adapted my teaching approach to cater to the diverse needs of my students.		0.75								
	PK6	I facilitated effective problem discussions among students during group activities.		0.72								
	PK1	Based on students' comprehension of the learning content, I modified the learning methodology.		0.71								
	PK5	I designed numerous group learning activities tailored to the students' needs.		0.68								
	PK3	In classroom instruction, I implemented a range of teaching strategies.		0.64								

Table 1. (*Continued*).

Variable	Child variable	Item	Factor load							α	CR	AVE
			1	2	3	4	5	6	7			
TCK	TCK5	I comprehend how to leverage technology to enhance understanding within my subject matter.			0.77					0.91	0.89	0.58
	TCK4	I am proficient in employing technology to participate in discussions pertaining to the scientific aspects of my subject matter.			0.76							
	TCK2	Regarding my research subject, I am aware of the techniques employed within the field.			0.74							
	TCK1	I recognize how advancements in technology have transformed my institution's approach in my subject area.			0.72							
	TCK6	I possess the capability to utilize specialized software for exploring various subject domains.			0.63							
	TCK3	I am aware of the latest technological developments currently occurring within my field of study.			0.60							
TK	TK2	I have regular access to multimedia resources and technologies.				0.76				0.89	0.89	0.62
	TK4	I possess the skill to employ multimedia technology effectively.				0.73						
	TK5	When utilizing multimedia, I am proficient in troubleshooting and resolving encountered issues.				0.71						
	TK1	I am knowledgeable about the evolution of multimedia technology.				0.66						
	TK3	I am familiar with a wide range of multimedia technologies.				0.64						
TPK	TPK4	I can select appropriate multimedia technology to augment students' learning capabilities.					0.78			0.89	0.91	0.67
	TPK1	I am capable of selecting appropriate multimedia technology to enhance and improve teaching methods.					0.73					
	TPK2	I have applied the multimedia technology I acquired across various teaching endeavors.					0.71					
	TPK5	I can guide students in utilizing multimedia and fostering collaborative learning.					0.64					
	TPK3	I can reflect on the effective utilization of diverse media technologies.					0.62					

Table 1. (*Continued*).

Variable	Child variable	Item	Factor load							α	CR	AVE
			1	2	3	4	5	6	7			
TPCK	TPCK1	I understand how to integrate teaching content, technology, and strategies to create cohesive instructional approaches.						0.73		0.88	0.89	0.62
	TPCK2	I can select suitable technology to enhance teaching tolerance and refine methodologies.						0.70				
	TPCK5	I am capable of designing inquiry-based activities supported by appropriate multimedia tools to facilitate students' understanding of subject matter.						0.69				
	TPCK4	I have planned activities that align with subject content, aiding students in utilizing suitable multimedia to construct expressions of subject knowledge.						0.68				
	TPCK3	I am adept at teaching course content while incorporating multimedia technology and curricular methodologies.						0.65				
CK	CK4	For the subjects I instruct, I appreciate the significance of the historical and developmental context of the theory.							0.73	0.91	0.90	0.65
	CK3	Regarding the subjects I teach, I have a solid grasp of the fundamental theories and content.							0.72			
	CK2	For each subject I teach, I possess a distinct subject-specific way of thinking.							0.63			
	CK1	For the subjects I instruct, I possess adequate knowledge reserves.							0.63			
	CK5	My extensive knowledge of the subjects I have mastered gives me confidence.							0.62			

Prior to conducting reliability and validity tests, factor analysis was carried out on the items, with the resultant KMO (Kaiser-Meyer-Olkin) and Bartlett's test statistics (KMO = 0.952, $\chi^2 = 9097.552$, $p < 0.0001$) confirming that the data fulfilled the prerequisites for factor analysis. Using SPSS 28.0, exploratory factor analysis was conducted on the scale, employing principal component analysis for factor extraction. The factor loading matrix was derived through orthogonal rotation utilizing the "varimax" method. Items were selected based on a factor loading threshold of 0.5, while factors were extracted if their eigenvalues exceeded 1. After eliminating two items with factor loadings below 0.5, the EFA results revealed that seven factors had eigenvalues greater than 1, collectively accounting for 70.18% of the total variance, suggesting the extraction of seven constructs.

The questionnaire's reliability was assessed using Cronbach's alpha coefficient and composite reliability (CR). Internal consistency reliability was measured by calculating Cronbach's α coefficient through SPSS 28.0, where a higher α score implies greater data reliability. Specifically, the α values for CK, PK, PCK, TCK, and TPK surpassed 0.9, demonstrating excellent reliability, while those for TPK and TPCK exceeded 0.8, indicating good reliability. Additionally, all CR values exceeded 0.7, confirming that the composite reliability was satisfactory. To evaluate the questionnaire's validity, factor loading and average variance extracted (AVE) were utilized. Factor loading values above 0.5 and an AVE value exceeding 0.5 signified good validity of the scale. The findings of the reliability and validity assessments are displayed in **Table 1**.

AMOS software was employed to perform a confirmatory factor analysis (CFA), aimed at evaluating the correspondence between factors and their corresponding measures, as well as assessing the congruence between the predefined factor model and the empirical data. The pathway diagram of the model, accompanied by standardized estimates, is illustrated in **Figure 2**.

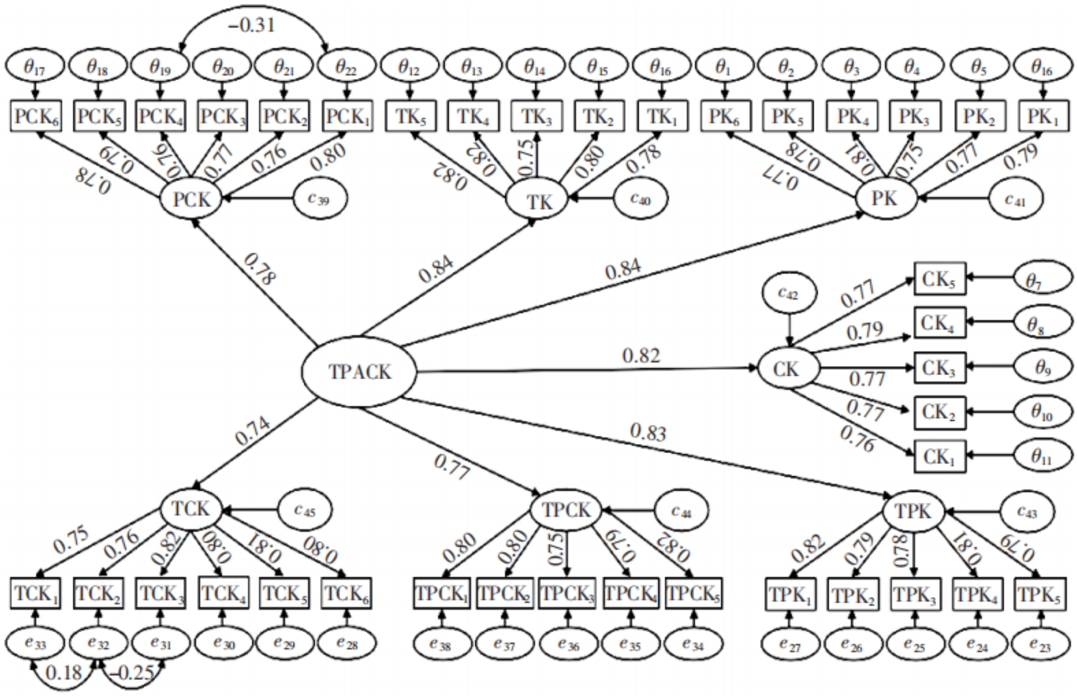

Figure 2. TPACK model path diagram and standardized estimated value of colleges normal students.

The assessment of the model's overall fit index shows its satisfactory conformity, which further corroborates the effectiveness of the scale, as presented in **Table 2**.

Table 2. Overall fit test of tpack model for colleges and universities teacher trainees.

Fitting index	Test result	Adaptation standard	Judge
χ^2/df	2.027	< 3.00	Yes
GFI	0.774	> 0.80	No
NFI	0.846	> 0.80	Yes
TLI	0.907	> 0.80	Yes
SRMR	0.026	< 0.10	Yes
RMSEA	0.066	> 0.08	Yes

4.2. Descriptive statistics and correlation analysis of TPACK dimensions of normal college students

The survey results indicate that teacher trainees in Chinese colleges and universities have a moderately high overall average score on the TPACK scale, ranging from 3.696 to 3.895. **Table 3** presents the average values of the various dimensions in ascending order: TCK, PK, PCK, followed by TPACK, TK, TPK, and CK.

Table 3. TPACK scores of normal students in colleges and universities.

Dimension	Quantity	Mean value	Standard deviation
PK	239	3.733	0.674
CK	239	3.895	0.675
TK	239	3.883	0.640
PCK	239	3.757	0.668
TPK	239	3.888	0.672
TCK	239	3.696	0.641
TPACK	239	3.814	0.599

The current research revealed correlation coefficients ranging from 0.871 to 0.944 between TPACK and the dimensions of PK, CK, TK, PCK, TPK and TCK. Notably, there is a marked correlation between TPACK and PK, PCK, and TCK, and an exceptionally strong correlation with CK, TK and TPK (refer to **Table 4**). Among the TPACK dimensions of teacher-training students, the correlation values, arranged from the lowest to the highest, are as follows: TCK, PK, PCK, CK, TK and TPK.

Table 4. TPACK correlation analysis for colleges and universities teacher trainees.

Dimension	PK	CK	TK	PCK	TPK	TCK	TPACK
PK	1.000						
CK	0.803**	1.000					
TK	0.793**	0.868**	1.000				
PCK	0.724**	0.746**	0.790**	1.000			
TPK	0.768**	0.843**	0.844**	0.849**	1.000		
TCK	0.691**	0.726**	0.723**	0.776**	0.800**	1.000	
TPACK	0.875**	0.916**	0.919**	0.896**	0.944**	0.871**	1.000

Note: [1] denotes $P < 0.01$, [2] denotes $P < 0.05$.

In order to delve deeper into the impact of each component of TPACK on the holistic development of teacher trainees in Chinese higher education institutions, a regression model was formulated, with TPACK serving as the dependent variable and PK, CK, TK, PCK, TPK, and TCK acting as the predictors. The outcomes of this regression analysis are presented in **Table 5**. The model's multicollinearity was assessed using the variance inflation factor (VIF), with a maximum VIF value of 6.335 across all regression models, which is beneath the threshold of 10, suggesting that potential multicollinearity would not compromise the regression findings. The regression model exhibited statistical significance ($F = 62.1$, $P < 0.01$) and the predictors collectively accounted for 99.7% of the variance in the dependent variable TPACK ($R^2 = 0.997$). All the predictors—PK, CK, TK, PCK, TPK, and TCK—were incorporated into the regression equation, yielding the model formula: TPACK = 0.150 + 0.153 × PK + 0.158 × CK + 0.158 × TK + 0.148 × PCK + 0.202 × TPK +

0.178 × TCK. The standardized coefficient values (β values) revealed that TPK had the most significant influence on TPACK development, followed by TCK, CK, TK, PK, and PCK in descending order.

Table 5. Multiple linear regression analysis of the impact of each element of TPACK on overall development.

Model	Unnormalized coefficient		Normalization factor	*t*	*P*	Collinearity statistics		Adjustment R^2	*F*
	B	**Standard error**				**Tolerance**	**VIF**		
Constant	0.015	0.015		1.025				0.997	61.2
PK	0.015	0.006	0.173	24.986	< 0.001	0.300	3.337		
CK	0.153	0.008	0.178	20.246	< 0.001	0.185	5.416		
TK	0.158	0.008	0.169	19.143	< 0.001	0.184	5.433		
PCK	0.148	0.007	0.165	21.220	< 0.001	0.236	4.229		
TPK	0.202	0.008	0.226	23.774	< 0.001	0.158	6.335		
TCK	0.178	0.006	0.191	28.490	< 0.001	0.318	3.147		

4.3. Analysis of interview results

In order to gain an in-depth understanding of the current situation of TPACK level and its influencing factors among Chinese university teacher trainees, this study used semi-structured interviews with some teacher trainees. The results of the interviews showed that most of the teacher trainees had a certain understanding of the TPACK concept, but there were still some problems and challenges in its practical application.

First, the interviewees generally reflected that although they had learned the relevant theoretical knowledge in the classroom, how to effectively integrate the technology, teaching content and teaching methodology in the actual teaching design and implementation process remained a difficult point. Teacher trainees indicated that they needed more practical opportunities to explore and apply TPACK, especially in real or simulated teaching environments.

Secondly, the interviews also revealed that teacher trainees had varying degrees of mastery of technology. Some teacher trainees were proficient in using multimedia teaching tools and online resources, while others were unfamiliar with certain technological tools. This suggests that colleges and universities should enhance the development of technology application skills in teacher education by providing diverse technology training and practice opportunities.

In assessing the differences in the effectiveness of the TPACK model of teaching and traditional teaching methods, the teacher trainees generally agreed that the TPACK model could better stimulate students' interest in learning and improve their engagement and independent learning ability. However, they also pointed out that to realize the TPACK mode of teaching, teachers need to have higher informationalized instructional design skills and technological operation skills.

In addition, the interviews revealed the importance teacher trainees attached to content knowledge (CK) and pedagogical knowledge (PK). Most of the teacher trainees believed that solid subject knowledge and effective teaching methods were the basis for becoming a good teacher. However, they also pointed out that current teacher education needs to be strengthened in terms of how to effectively integrate this knowledge with technology.

Finally, the results of the interviews indicated that the teacher trainees generally believed that their TPACK levels were significantly enhanced through their participation in teaching practicums and simulation activities. These practical activities not only helped them to transform their theoretical knowledge into practical skills, but also enhanced their ability to solve practical teaching problems.

4.4. Strategies for improving the informatization ability of normal college students

In order to improve the teacher trainees' information technology skills, the following improvement strategies were proposed based on the results of the study: utilizing the TPK as a focus and integrating other components such as the CK and PCK to promote TPACK proficiency.

Correlation analysis indicates that TPK, which signifies the integration of technology knowledge, exhibits the strongest correlation with TPACK. Furthermore, the findings of multiple regression analysis imply that TPK has the most substantial influence on the level of TPACK. Consequently, it is advisable to prioritize enhancing the TPACK level of education students by focusing on TPK. This strategy would facilitate the integration of information technology knowledge with pedagogical content knowledge among education students, ultimately resulting in an elevation of their information literacy. But it is also crucial to emphasize the imparting of pedagogical knowledge to education students. However, merely acquiring and comprehending pedagogical knowledge in isolation is inadequate. Rather, we must underscore the incorporation of information technology as a vital component within cohesive teaching approaches. By educating on instructional methodologies, we can steer education students towards selecting, applying, and refining information technology. Our objective is to enable the implementation of "technology-infused" teaching and foster the ongoing advancement of TPACK among education students. Additionally, it is prudent to advocate for the adoption of novel intelligent training platforms or methodologies to facilitate online practice, evaluations, and enhancements in subject instruction for education students. The advancements in information technology have furnished numerous avenues and prospects for the informatization of subject teaching methodology knowledge among education students. Leveraging network-based learning environments and online teaching and training platforms can aid education students in choosing suitable technological tools based on the attributes, demands, and objectives of subject teaching. Consequently, this aids in elevating their TPACK level.

In addition, the development of teacher trainees' TPACK cannot be separated from the interaction between other elements such as PCK and CK. In order to further enhance teacher trainees' information-based teaching ability, the following strategies are suggested: first, teacher trainees' understanding and application of PCK should be strengthened. Through case studies, simulated teaching and reflective practice, teacher trainees should gain a deeper understanding of how to combine subject knowledge with pedagogy, so as to better adapt to different learning contexts and student needs.

Secondly, the deepening of CK should be emphasized. Teacher trainees are encouraged to study in depth the core concepts, principles and methods of the disciplines they teach, and to improve their disciplinary expertise by participating in academic seminars, reading specialized literature and conducting disciplinary research projects. Again, the integration of TK with pedagogical knowledge should be promoted. Through organizing workshops, seminars and technology training, teacher trainees should be helped to master the latest educational technology tools and resources, and explore how to effectively integrate these technologies into instructional design and implementation. Finally, teacher trainees' practical teaching experience should be strengthened. Through on- and off-campus internships and teaching practice, teacher trainees can apply what they have learned in real or simulated teaching environments, and continue to improve their teaching skills and information-based teaching abilities through practical reflection and peer evaluation.

Through the implementation of the above strategies, it can effectively promote the balanced development of teacher trainees in all dimensions of TPACK and lay a solid foundation for them to become excellent teachers in information-based teaching in the future.

4.5. Construction and application of teaching system of TPACK integration model

According to the aforementioned research results, we can see that TPK, focused on new media technology, is of the greatest significance in influencing the development of TPACK. The integration of new media technology has brought about a profound combination of information technology and teaching practices, creating a dual-subject classroom environment. This has allowed for inquiry-based learning for students and facilitated the establishment of individualized knowledge frameworks. However, the TPACK framework has many limitations, such as the selection of teaching topics and the application of teachers' teaching methods. Therefore, when constructing the TPACK integration model (**Figure 3**), we will deeply integrate TK and CK and use TPK to design learning situations and stimulate students' interest in learning through PPT, pictures, videos, charts, etc.

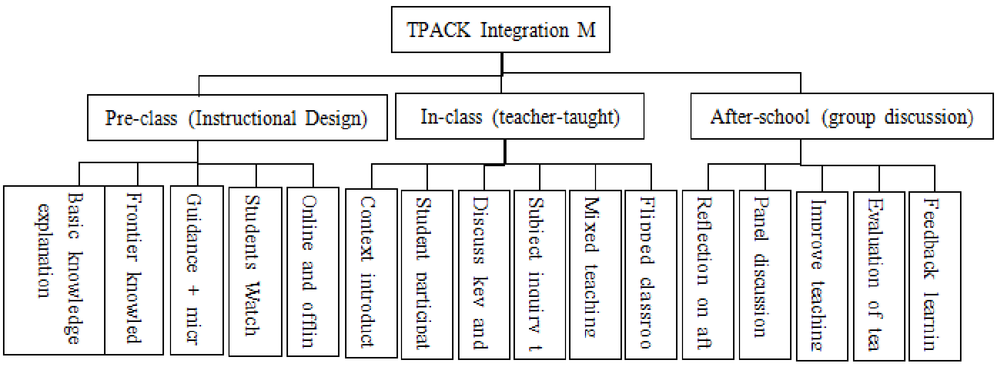

Figure 3. Teaching system of TPACK integrated model.

Utilizing the aforementioned model as a foundation, we propose several implementations of the TPACK integration framework within the realm of educational system reform:

1) Encourage autonomous learning by providing resources. In accordance with the self-actualization needs outlined in humanistic learning theory, electronic whiteboards are employed to distribute pre-class preview materials to students, encompassing MOOCs, micro-lectures, educational slides, pre-assessment quizzes, and other learning assignments. Motivated by these needs, students engage in independent study using smartphones, PCs, and other devices, previewing the content and submitting their work prior to class. This approach fosters a sense of anticipation among students towards learning and stimulates their enthusiasm. By examining the feedback data obtained from students' previews, educators can choose and customize effective instructional approaches and educational technologies.
2) Assess the academic environment and establish definitive goals. The pre-class phase of intelligent instruction comprises a holistic learning sequence. Initially, educators evaluate students' prior academic achievements and understanding of fundamental concepts through electronic whiteboards and virtual classrooms, thereby setting instructional objectives. Subsequently, students independently tackle the preview quizzes assigned by the instructors and submit them to the platform, yielding a substantial dataset for educators to analyze. Additionally, students can engage in discussions about the difficulties encountered during the preview phase within the class learning discussion group. Ultimately, based on the feedback obtained from the goal setting, preview tasks, and quizzes, the instructor conducts a comprehensive analysis of the students' learning progress, gains an accurate understanding of their educational requirements, develops an appropriate instructional design plan, and implements teaching that is centered on learning.
3) To spark interest, introduce captivating scenarios. During actual instruction, it is crucial to leverage the image and video playback capabilities of electronic whiteboards, alongside the game-based design of classroom activities, to establish engaging teaching contexts. Suitable methods should be selected flexibly to invigorate the classroom atmosphere. The classroom ambiance plays a pivotal role in influencing teaching effectiveness (Wilson and Myers, 2000). In alignment with educational objectives, educators should create scenarios tailored to students' characteristics, incorporate suspense, and evoke intense curiosity among students, thereby stimulating their learning interest and initiative. Since scenario introductions effectively stimulate sensory engagement, they are highly favored by students. An engaging and innovative scenario can rapidly grab students' attention and immerse them in the learning process, rendering it a commendable and adoptable teaching method. The contextualization must be tailored to the curriculum content, requiring careful planning by educators. Common contextual designs include: Firstly, the scenario of film and television animations, where multimedia should be fully utilized to present problem scenarios in animated form. Secondly, the problem-solving scenario. The essence of intelligent teaching lies in problem analysis and resolution. By carefully designing problems beforehand, everyday life-based problems can generally spark students' interest and make them genuinely appreciate the close connection between knowledge and life. Although scenario introduction constitutes only a

fraction of the teaching process, it can invigorate the overall learning atmosphere and propel students to complete teaching tasks with enthusiasm.

4) Situation introduction to stimulate interest. The flipped classroom model empowers students, establishes a proper educational philosophy emphasizing student-centeredness, active learning, collaborative inquiry, and intergroup interaction, thereby facilitating independent knowledge acquisition. Educators should eschew the mindset of immediate success and instead consistently monitor students' learning progress, adjusting the classroom pace to suit. By presenting problematic scenarios conducive to independent exploration, educators encourage active student participation. Learning tasks are dispensed to students' tablets via electronic whiteboards in the form of inquiries, prompting exploratory efforts. Guided by these goals and tasks, students engage in online discussions and problem-solving. Educators ought to endeavor to foster an environment that encourages inquiry and thoughtfully incorporate pertinent educational resources. By comprehending students' learning progress, educators can devise opportunities and provide tailored support that addresses specific tasks and students' problem-solving needs. Intelligent technology assists students in overcoming obstacles and enhances their mastery of intricate knowledge areas.

5. Conclusion

The results of this research reveal that the current proficiency level of technology-integrated subject matter pedagogical knowledge among teacher education students in Chinese colleges and universities stands at a moderately advanced stage. In recent times, policy-induced advancements in information-centric teaching have been evident, resulting in a notable enhancement in the amalgamation of information technology with the education and teaching of normal students at the collegiate level. The sequence of average values across diverse dimensions, arranged in ascending order, is as follows: TCK < PK < PCK < TPACK < TK < TPK < CK. In terms of individual dimensions, the CK value is the highest, indicating that Chinese university teacher education students possess strong subject matter expertise. From a multidimensional perspective, the values of the composite knowledge components PCK and TCK remain comparatively low, hinting at the potential for further enhancement in the integration of pedagogical understanding, information technology, and subject content among teacher education students in Chinese universities.

Among Chinese university teacher education students, a strong correlation is observed between TPACK and various dimensions including PK, PCK and TCK. Furthermore, an exceptionally high correlation exists between TPACK and CK, TK, and TPK. The sequence of correlation coefficients among the TPACK-related dimensions for these students, from the lowest to the highest, is TCK < PK < PCK < CK < TK < TPK. A multiple regression analysis reveals that TPK exerts the most prominent influence on the development of TPACK. Simultaneously, TPK, alongside TCK and PCK, demonstrates significant effects on TPACK progression, suggesting that a holistic grasp of knowledge substantially contributes to the advancement of TPACK.

Furthermore, the findings indicate that TPK holds the utmost significance in the multifaceted development of TPACK. In particular, three vital knowledge components—Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), and Technological Pedagogical Knowledge (TPK), which pertain to technology integration, are pivotal in advancing TPACK. Consequently, it is advisable to prioritize enhancing the TPACK levels of teacher education students by focusing on the TPK dimension. This will foster the integration of information technology and teaching methodologies within their knowledge framework, thereby bolstering their informational competencies. The evolution of TPACK is intertwined with other elements, such as CK and PCK. Therefore, merely concentrating on the enhancement of technology, pedagogy, or subject-specific knowledge should be eschewed. Instead, greater emphasis should be placed on the synthesis of these components. To accomplish this, the development of cross-disciplinary integration courses should be increased. Additionally, leveraging both on-campus training facilities and off-campus practical sites enables flexible and apt organization of practical activities, ultimately enriching the composite TPACK knowledge of teacher trainees.

Ultimately, this study delves into a novel educational system, grounded in the analysis of the TPACK integration framework, which incorporates the TPACK model within the ambit of smart classrooms. It commences with the three phases of pre-class preparation, in-class engagement, and post-class reinforcement, seamlessly incorporating artificial intelligence techniques to augment students' learning enthusiasm and intrinsic drive. This approach fosters an active learning milieu where students exercise their initiative and agency. Furthermore, it assists educators in comprehending students' learning progression and adopting flexible teaching strategies, thereby enhancing the overall quality of education and instruction.

In summary, this study furnishes a theoretical foundation and pragmatic guidance for elevating the TPACK proficiency of teacher education students in colleges and universities. It contributes to advancing the construction and implementation of China's intelligent classroom teaching system and establishes a groundwork for nurturing a high-quality teaching workforce that aligns with future educational demands.

Author contributions: Conceptualization, YL and MNHBMS; methodology, YL; software, YL; validation, YL and MNHBMS; formal analysis, YL; investigation, IN; resources, YL; data curation, YL; writing—original draft preparation, YL; writing-review and editing, MNHBMS; visualization, YL; supervision, MNHBMS; project administration, MNHBMS. All authors have read and agreed to the published version of the manuscript.

Funding: The work was supported by the Ministry of Higher Education under the Fundamental Research Grant Scheme (FRGS) (FRGS/1/2024/SSI09/UTM/02/4).

Conflict of interest: The authors declare no conflict of interest.

References

Agnes Kukulska-Hulme. (2018). Smart Learning with Mobile Devices. http://blogs.ubc.ca/newliteracies/files/2011/12/Kukulska-Hulme.pdf.

Balyer, A., & Öz, Ö. (2018). Academicians' views on digital transformation in education. International Online Journal of Education and Teaching (IOJET), 5(4), pp. 809-830.http://iojet.org/index.php/IOJET/article/view/441/295

Becta. (2004）.A review of the research literature on barriers to the uptake of ICT by teachers. British Educational Communications and Technology Agency, pp.1-29.

Brantley-Dias L, & Ertmer P A. (2013). Goldilocks and TPACK: Is the construct 'just right?'. Journal of Research on Technology in Education,46(2), pp.103-128.https://doi.org/10.1080/15391523.2013.10782615

Ching Sing Chai, (2013). Joyce Hwee Ling Koh, Chin-Chung Tsai. A review of technological pedagogical content knowledge. Educational Technology & Society, 16(2), pp.34.

Cox, S. (2008). A Conceptual Analysis of Technological Pedagogical Content Knowledge. Brigham Young University.

Davis, N., Preston, C., & Sahin, I. (2009). Training teachers to use new technologies impacts multiple ecologies: evidence from a national initiative. British Journal of Educational Technology, 40(5), pp. 861–878. https://doi.org/10.1111/j.1467-8535.2008.00875.x

Goddard, N. D. R., Kemp R M J & Lane R. (1997). An overview of intelligent technology.Packaging Technology and Science: An International Journal. 10(3), pp.129-143. https://doi.org/10.1016/j.tifs.2016.02.008

Hennessy, S., Wishart, J., Whitelock, D., Deaney, R., Brawn, la Velle, L., McFarlane, A., et al. (2007). Pedagogical approaches for technology-integrated science teaching. Computers & Education, 48(1), pp.137–152. https://doi.org/10.1016/j.compedu.2006.02.004

Herold, B. (2016). Technology in education: an overview. Educ. Week ,20, pp.129–141.

Hilton, J. T. (2016). A case study of the application of SAMR and TPACK for reflection on technology integration into two social studies classrooms. Soc. Stud. 107, pp.68–73. https://doi.org/10.1080/00377996.2015.1124376

Horne, S. V., Murniati, C. T., Saichaie, K., et al. (2014). Using Qualitative Research to Assess Teaching and Learning in Technology-Infused TILE Classrooms. New Directions for Teaching&Learning, (137), pp.17–26. https://doi.org/10.1002/tl.20082

J.Voogt, P.FIsser, N. & Pareja Roblin. (2013). Technological pedagogical content knowledge – a review of the literature. Journal of Computer Assisted Learning, 29, pp.109.https://doi.org/10.1111/j.1365-2729.2012.00487.x

Jimoyiannis, A., & Komis, V. (2007). Examining teachers' beliefs about ICT in education: implications of a teacher preparation programme. Teacher Development, 11(2), pp. 149–173.https://doi.org/10.1080/13664530701414779

Koehler, M. J. & Mishra, P. (2008). Introducing TPACK. In AACTE Committee on Innovation and Technology. Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators (pp. 3-29). New York: Routledge.

Koehler, M. J., Mishra, P., Kereluik, K., Shin, T. S., & Graham, C. R. (2014). "The technological pedagogical content knowledge framework," in Handbook of research on educational communications and technology, eds J. Spector, M. Merrill, J. Elen and M. Bishop (New York, NY: Springer), pp.101–111.

Koehler, M. J., & Mishra, P. (2005). What happens when teachers design educational technology? The development of technological pedagogical content knowledge. Journal of Educational Computing Research, 32(2), pp.131-152. https://doi.org/10.2190/0EW7-01WB-BKHL-QDYV

Lin,H. C Tu, Y. F.,Hwang, G. J.,& Huang,H. (2021). From precision education to precision medicine. Educational Technology & Society ,24(1), pp.123-137.

Mishra，P., & Koehler，M. J. (2006). Technological pedagogical content knowledge: A framework for integrating technology in teacher knowledge.Teachers College Record,108(6),pp.1017-1054.

Montebello, M. (2018). AI injected e-learning: The future of online education. Springer.

Palmisano S J. (2008). A smarter planet:the next leadership agenda. IBM. November, 6:1-8.

S. Seufert, J., & Guggemos, M. (2021). Sailer Technology-related knowledge, skills, and attitudes of pre-and in-service teachers: The current situation and emerging trends. Computers in Human Behavior, 115, pp.106552,

Schmid M., Brianza E., & Petko D.（2020). Developing a short assessment instrument for Technological Pedagogical Content Knowledge (TPACK.xs) and comparing the factor structure of an integrative and a transformative model -science direct. Computers & Education,157, pp.1-12. https://doi.org/10.1016/j.compedu.2020.103967

Wilson B. G., & Myers K. M. (2000). Situated cognition in theoretical and practical context.Theoretical foundations of learning environments,pp.57-88.

Ying-Shao Hsu. （2015). Development of science teachers’ TPACK. Springer, Science+BusinessMidia, Singapore:1.