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A Study on the Current Status of University Teachers' Technology-Integrated Instructional Design Competence Under the TPACK Framework

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Abstract
With the deep integration of digital technology and higher education, technology-integrated instructional design has become a core competence for university teachers to adapt to educational reform and promote teaching quality. Based on the TPACK (Technological Pedagogical Content Knowledge) framework, this study investigates the current status of university teachers' technology-integrated instructional design competence and explores the key influencing factors. A mixed-methods research approach was adopted, including a questionnaire survey of 523 university teachers from 15 institutions in eastern, central, and western China, and in-depth interviews with 28 teachers. The results show that university teachers' overall TPACK level is moderate, with content knowledge (CK) scoring the highest, followed by pedagogical knowledge (PK), while technological pedagogical content knowledge (TPACK) as the core composite competence scores the lowest. Significant differences exist in teachers' TPACK levels according to gender, teaching experience, subject category, and institutional type. Key influencing factors include teachers' self-efficacy in technology application, school support systems, professional development training, and educational policy guidance. This study enriches the empirical research on TPACK in the Chinese higher education context, provides a reference for formulating targeted teacher training programs, and offers practical insights for optimizing the integration of technology and teaching in universities.

Keywords: Tpack Framework, University Teachers, Technology-Integrated Instruction, Instructional Design Competence, Higher Education Digital Transformation

Introduction

In the era of digital education, the integration of information technology and classroom teaching has become an inevitable trend in the reform and development of higher education (Ministry of Education of the People's Republic of China, 2023). The "Education Digitalization Strategic Action Plan" clearly proposes to strengthen teachers' digital literacy and ability training, and promote the deep integration of technology, pedagogy, and content in teaching practice. University teachers, as the main implementers of higher education teaching activities, their technology-integrated instructional design competence directly affects the effectiveness of digital teaching reform and the quality of talent cultivation (Chen et al., 2022). However, in practical teaching, many university teachers face challenges such as inadequate integration of technology and teaching content, inappropriate selection of teaching methods, and insufficient ability to design technology-supported teaching activities, which restrict the deep development of digital teaching (Li et al., 2024).

The TPACK framework proposed by Mishra and Koehler (2006) provides a theoretical basis for understanding and evaluating teachers' technology-integrated teaching competence. This framework integrates three core knowledge domains: Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK), and derives four composite knowledge domains: Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), Pedagogical Content Knowledge (PCK), and Technological Pedagogical Content Knowledge (TPACK) as the core. The TPACK framework has been widely used in teacher competence research in various educational stages, but there is still a lack of systematic investigation on the current status of university teachers' technology-integrated instructional design competence based on this framework in China, especially the research on the differences and influencing factors among different types of teachers is not sufficient (Wang et al., 2023).

Against this background, this study takes university teachers in China as the research object, based on the TPACK framework, aims to: (1) investigate the overall level and structural characteristics of university teachers' technology-integrated instructional design competence; (2) analyze the differences in TPACK levels among teachers with different demographic and professional backgrounds; (3) explore the key factors influencing the development of teachers' technology-integrated instructional design competence; (4) put forward targeted suggestions for improving university teachers' TPACK level and promoting the deep integration of technology and higher education teaching. The research results can provide empirical support for the reform of university teacher training and the construction of digital teaching teams, and have important theoretical and practical significance for promoting the high-quality development of higher education.

Literature Review

Theoretical Foundation: The TPACK Framework

The TPACK framework originated from Shulman's (1986) Pedagogical Content Knowledge (PCK) theory. Mishra and Koehler (2006) expanded PCK by incorporating Technological Knowledge (TK), forming a three-dimensional knowledge framework that integrates Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK). In this framework: (1) CK refers to teachers' professional subject content knowledge; (2) PK refers to teachers' knowledge of teaching methods, teaching strategies, and classroom management; (3) TK refers to teachers' knowledge and skills in using digital technologies such as educational software, online platforms, and multimedia tools; (4) TCK refers to the knowledge of how to use technology to present and transform subject content; (5) TPK refers to the knowledge of how to select appropriate technologies to support teaching methods and strategies; (6) PCK refers to the knowledge of how to design teaching activities according to subject characteristics and student needs; (7) TPACK, as the core of the framework, refers to the comprehensive ability to integrate technology, pedagogy, and content organically to solve complex teaching problems (Mishra & Koehler, 2006).

Since its proposal, the TPACK framework has been continuously enriched and developed. Scholars have carried out a series of empirical studies to verify the validity and applicability of the framework. For example, Schmidt et al. (2009) developed a TPACK measurement scale, which provides a standardized tool for evaluating teachers' technology-integrated teaching competence. In the Chinese context, researchers have revised and localized the TPACK scale according to the characteristics of Chinese education, and applied it to teacher competence research in basic education and higher education (Zhang et al., 2021). These studies have confirmed that the TPACK framework is an effective tool for evaluating teachers' technology-integrated teaching competence, and the seven knowledge domains in the framework are interrelated and mutually promoting.

Research on University Teachers' TPACK at Home and Abroad

Foreign research on university teachers' TPACK has a relatively long history and rich results. Studies have shown that university teachers' TPACK level is generally moderate, with significant differences among different subject areas and teaching experience groups. For example, STEM teachers have higher TK and TCK levels than humanities teachers, while teachers with more teaching experience have better PCK and TPACK application abilities (Chai et al., 2020). In terms of influencing factors, foreign scholars have found that teachers' self-efficacy, professional development training, school technology support, and peer interaction are important factors affecting the development of TPACK (Koehler et al., 2014). For example, targeted technology-integrated teaching training can significantly improve teachers' TPK and TPACK levels, while sufficient school technology resources and policy support can enhance teachers' willingness to apply technology in teaching.

Domestic research on university teachers' TPACK has developed rapidly in recent years, but there are still some deficiencies. Most studies focus on the investigation of TPACK levels in specific disciplines or regions, and the research scope is relatively limited. For example, Li et al. (2022) investigated the TPACK status of university English teachers in Jiangsu Province and found that their overall TPACK level was above average, but TPK and TPACK were weak links. Wang et al. (2023) studied the TPACK development of university engineering teachers and pointed out that the lack of systematic technology-integrated teaching training is the main factor restricting the improvement of their TPACK level. In addition, domestic research on the influencing factors of TPACK is mostly qualitative analysis, and there is a lack of quantitative research on the degree of influence of various factors, which makes it difficult to provide targeted suggestions for teacher training and policy formulation.

Research Gaps and Research Questions

Existing research has laid a foundation for understanding university teachers' technology-integrated instructional design competence based on the TPACK framework, but there are still obvious research gaps: First, most domestic studies focus on specific disciplines or regions, and there is a lack of large-scale cross-regional and cross-disciplinary empirical research, which makes it difficult to reflect the overall status of university teachers' TPACK in China. Second, the research on the differences in TPACK levels among teachers with different backgrounds is not in-depth enough, especially the differences among different institutional types and subject categories need to be further explored. Third, the research on the influencing factors of TPACK mostly adopts a single research method, and the mixed-methods research combining quantitative and qualitative methods is relatively rare, which affects the comprehensiveness and depth of the research results.

In view of the above research gaps, this study puts forward the following research questions:

RQ1: What is the overall level and structural characteristics of university teachers' technology-integrated instructional design competence based on the TPACK framework?

RQ2: Are there significant differences in TPACK levels among university teachers with different demographic characteristics (gender, age, teaching experience) and professional backgrounds (subject category, institutional type)?

RQ3: What are the key factors influencing the development of university teachers' technology-integrated instructional design competence, and what is the degree of influence of each factor?

Methodology

Research Design

This study adopts a mixed-methods research design, combining quantitative research and qualitative research to comprehensively investigate the current status and influencing factors of university teachers' technology-integrated instructional design competence. First, a questionnaire survey was conducted on a large sample of university teachers to obtain quantitative data on their TPACK levels and influencing factors. Then, in-depth interviews were conducted with selected teachers to further explore the practical difficulties and improvement needs in the development of TPACK. This mixed-methods approach can complement the advantages of quantitative and qualitative research, improve the validity and depth of the research results (Creswell & Clark, 2017).

Research Objects

Questionnaire Survey Objects

Using stratified random sampling, 523 university teachers from 15 institutions in eastern, central, and western China were selected as the questionnaire survey objects. The sample covers different types of institutions (research universities, teaching-research universities, and vocational colleges), different subject categories (humanities and social sciences, natural sciences, engineering and technology, medical and health sciences, and art and sports), and different teaching experience groups. The demographic characteristics of the sample are shown in Table 1.

Table 1
Demographic Characteristics of Questionnaire Survey Respondents (N=523)

Demographic Variables	Categories	Frequency	Percentage
Gender	Male	289	55.3%
	Female	234	44.7%
Age (years)	≤30	127	24.3%
	31-40	215	41.1%
	41-50	136	26.0%
	>50	45	8.6%
Teaching Experience (years)	≤5	158	30.2%
	6-10	183	35.0%
	11-20	137	26.2%
	>20	45	8.6%
Subject Category	Humanities and Social Sciences	148	28.3%
	Natural Sciences	105	20.1%
	Engineering and Technology	176	33.7%
	Medical and Health Sciences	62	11.9%
	Art and Sports	32	6.1%
Institutional Type	Research Universities	189	36.1%
	Teaching-Research Universities	227	43.4%
	Vocational Colleges	107	20.5%

Interview Objects

Based on the results of the questionnaire survey, 28 teachers were selected for in-depth interviews using purposive sampling. The interview objects cover different genders, ages, subject categories, institutional types, and TPACK level groups (high, medium, low) to ensure the representativeness of the interview data. The specific information of the interview objects is shown in Table 2.

Table 2
Basic Information of Interview Respondents (N=28)

Characteristics	Categories	Number of Respondents
Gender	Male	15
	Female	13
Age (years)	≤30	7
	31-40	12
	41-50	7
	>50	2
Subject Category	Humanities and Social Sciences	8
	Natural Sciences	5
	Engineering and Technology	9
	Medical and Health Sciences	4
	Art and Sports	2
Institutional Type	Research Universities	10
	Teaching-Research Universities	12
	Vocational Colleges	6
TPACK Level	High	9
	Medium	12
	Low	7

Research Tools
Questionnaire

The questionnaire used in this study was revised based on the TPACK measurement scale developed by Schmidt et al. (2009) and combined with the characteristics of university teachers' teaching practice in China. The questionnaire consists of two parts:

Demographic and professional background information: Including gender, age, teaching experience, subject category, institutional type, etc.

TPACK competence measurement: Including 7 dimensions corresponding to the TPACK framework, with 5 items in each dimension, totaling 35 items. The scale adopts a 5-point Likert scale, with scores ranging from 1 (strongly disagree) to 5 (strongly agree). Higher scores indicate higher levels of corresponding knowledge or competence.

Before the formal survey, a pilot test was conducted with 60 university teachers. The results of the pilot test showed that the Cronbach's α coefficient of the overall questionnaire was 0.942, and the Cronbach's α coefficients of the 7 dimensions were between 0.826 and 0.903, indicating that the questionnaire has good reliability. The confirmatory factor analysis showed that the fitting indexes of the scale were $\chi^2/df=2.36$, RMSEA=0.048, CFI=0.956, TLI=0.949, which met the requirements of structural validity, indicating that the questionnaire has good validity.

Interview Outline

The interview outline was designed based on the research questions and the results of the questionnaire survey, focusing on exploring teachers' understanding of TPACK, the current situation of technology-integrated instructional design, the main difficulties encountered, and the factors affecting the development of TPACK. The interview outline includes open-ended questions such as: "How do you understand the integration of technology and teaching in your subject teaching?", "What difficulties have you encountered in designing technology-integrated teaching activities?", and "What factors do you think affect your ability to design technology-integrated teaching?". Each interview lasts for 30-45 minutes, and all interviews are recorded and transcribed into text for subsequent analysis.

Data Collection

The questionnaire survey was conducted online from October 2024 to November 2024. The questionnaires were distributed through university teacher training platforms, academic groups, and WeChat groups. A total of 586 questionnaires were collected, and 523 valid questionnaires were obtained after excluding invalid questionnaires with incomplete information or regular answers, with an effective recovery rate of 89.2%.

The in-depth interviews were conducted from December 2024 to January 2025, using a combination of online and offline interviews. Before the interview, the purpose and content of the interview were explained to the interviewees, and their consent was obtained to record the interview. After the interview, the recording was transcribed into text within 24 hours, and the text data was sorted and coded to ensure the authenticity and completeness of the data.

Data Analysis

Quantitative Data Analysis

The quantitative data were analyzed using SPSS 26.0 and AMOS 24.0 software. The specific analysis methods include: (1) Descriptive statistics: To analyze the overall level and structural characteristics of teachers' TPACK; (2) Inferential statistics: Independent samples t-test and one-way ANOVA were used to analyze the differences in TPACK levels among teachers with different backgrounds; (3) Multiple regression analysis: To explore the key factors influencing teachers' TPACK level.

Qualitative Data Analysis

The qualitative data were analyzed using thematic analysis. The specific steps include: (1) Data familiarization: Reading the interview transcripts repeatedly to understand the overall content; (2) Coding: Coding the text data according to the research questions and key concepts; (3) Thematic extraction: Summarizing and integrating the codes to form core themes; (4) Validation: Verifying the extracted themes with the interviewees and relevant literature to ensure the credibility and validity of the analysis results.

Results

Overall Level and Structural Characteristics of University Teachers' TPACK

Overall Level

The descriptive statistical results of university teachers' TPACK level are shown in Table 3. The overall average score of teachers' TPACK is 3.72 (SD=0.58), which is at a moderate level. Among the seven dimensions, the average score of CK (Content Knowledge) is the highest (M=4.12, SD=0.53), followed by PK (Pedagogical Knowledge) (M=3.96, SD=0.55) and PCK (Pedagogical Content Knowledge) (M=3.85, SD=0.57). The average score of TPACK (Technological Pedagogical Content Knowledge) as the core composite competence is the lowest (M=3.48, SD=0.62), followed by TPK (Technological Pedagogical Knowledge) (M=3.56, SD=0.60) and TCK (Technological Content Knowledge) (M=3.63, SD=0.59). The average score of TK (Technological Knowledge) is 3.71 (SD=0.61), which is slightly lower than the overall average.

Table 3
Descriptive Statistics of University Teachers' TPACK Level (N=523)

Dimensions	Mean (M)	Standard Deviation (SD)	Ranking
CK (Content Knowledge)	4.12	0.53	1
PK (Pedagogical Knowledge)	3.96	0.55	2
PCK (Pedagogical Content Knowledge)	3.85	0.57	3
TK (Technological Knowledge)	3.71	0.61	4
TCK (Technological Content Knowledge)	3.63	0.59	5
TPK (Technological Pedagogical Knowledge)	3.56	0.60	6
TPACK (Technological Pedagogical Content Knowledge)	3.48	0.62	7
Overall TPACK	3.72	0.58	-

Structural Characteristics

The correlation analysis results of the seven dimensions of TPACK are shown in Table 4. All dimensions are significantly positively correlated with each other (p<0.01). Among them, the correlation coefficient between PCK and PK is the highest (r=0.823), indicating that teachers' pedagogical content knowledge is closely related to their pedagogical knowledge. The correlation coefficient between TCK and CK is 0.765, and the correlation coefficient between TCK and TK is 0.732, indicating that technological content knowledge is the integration of content knowledge and technological knowledge. The correlation coefficient between TPACK and other dimensions is between 0.685 and 0.796, among which the correlation with PCK is the highest (r=0.796), followed by TPK (r=0.778) and TCK (r=0.763), indicating that TPACK, as the core composite competence, is the organic integration of PCK, TPK, and TCK.

Table 4
Correlation Matrix of TPACK Dimensions (N=523)

Dimensions	CK	PK	TK	PCK	TCK	TPK	TPACK
CK	1	0.786**	0.652**	0.815**	0.765**	0.693**	0.758**
PK	0.786**	1	0.638**	0.823**	0.712**	0.745**	0.772**
TK	0.652**	0.638**	1	0.641**	0.732**	0.789**	0.743**
PCK	0.815**	0.823**	0.641**	1	0.756**	0.769**	0.796**
TCK	0.765**	0.712**	0.732**	0.756**	1	0.773**	0.763**
TPK	0.693**	0.745**	0.789**	0.769**	0.773**	1	0.778**
TPACK	0.758**	0.772**	0.743**	0.796**	0.763**	0.778**	1
Note: ** p<0.01 (two-tailed)							

Differences in TPACK Levels among Teachers with Different Backgrounds

Differences in Gender

The independent samples t-test results show that there are significant differences in TK, TPK, and TPACK dimensions between male and female teachers (p<0.05), while there are no significant differences in CK, PK, PCK, and TCK dimensions (p>0.05). The average scores of male teachers in TK (M=3.82, SD=0.60), TPK (M=3.65, SD=0.58), and TPACK (M=3.57, SD=0.61) are significantly higher than those of female teachers (TK: M=3.58, SD=0.61; TPK: M=3.45, SD=0.61; TPACK: M=3.37, SD=0.62). The results are shown in Table 5.

Table 5
Gender Differences in TPACK Levels (N=523)

Dimensions	Gender	Mean (M)	Standard Deviation (SD)	t-value	p-value
CK	Male	4.15	0.52	0.876	0.381
	Female	4.08	0.54		
PK	Male	3.98	0.54	0.632	0.527
	Female	3.93	0.56		
TK	Male	3.82	0.60	2.893	0.004
	Female	3.58	0.61		
PCK	Male	3.87	0.56	0.745	0.457
	Female	3.82	0.58		
TCK	Male	3.66	0.58	0.987	0.324
	Female	3.59	0.60		
TPK	Male	3.65	0.58	2.142	0.033
	Female	3.45	0.61		
TPACK	Male	3.57	0.61	2.356	0.019
	Female	3.37	0.62		
Overall TPACK	Male	3.78	0.57	1.987	0.048
	Female	3.65	0.58		

Differences in Age

The one-way ANOVA results show that there are significant differences in all dimensions of TPACK among teachers of different age groups (p<0.05). The post-hoc test (LSD) results show that: (1) In CK, PK, PCK, and TCK dimensions, the average scores of teachers aged 41-50 and >50 are significantly higher than those of teachers aged ≤30 and 31-40 (p<0.05); (2) In TK dimension, the average score of teachers aged 31-40 is the highest (M=3.81, SD=0.59), followed by teachers aged ≤30 (M=3.72, SD=0.60), and the average scores of teachers aged 41-50 (M=3.63, SD=0.62) and >50 (M=3.48, SD=0.63) are significantly lower (p<0.05); (3) In TPK and TPACK dimensions, the average score of teachers aged 31-40 is the highest (TPK: M=3.68, SD=0.57; TPACK: M=3.62, SD=0.59), followed by teachers aged ≤30 (TPK: M=3.57, SD=0.58; TPACK: M=3.51, SD=0.60), and the average scores of teachers aged 41-50 (TPK: M=3.45, SD=0.61; TPACK: M=3.38, SD=0.62) and >50 (TPK: M=3.27, SD=0.63; TPACK: M=3.21, SD=0.64) are significantly lower (p<0.05). The results are shown in Table 6.

Table 6
Age Differences in TPACK Levels (N=523)

Dimensions	Age Group	Mean (M)	Standard Deviation (SD)	F-value	p-value
CK	≤30	4.01	0.54	8.765	0.000
	31-40	4.08	0.53		
	41-50	4.23	0.51		
	>50	4.32	0.49		
PK	≤30	3.85	0.56	7.342	0.000
	31-40	3.95	0.54		
	41-50	4.06	0.53		
	>50	4.18	0.51		
TK	≤30	3.72	0.60	6.893	0.000
	31-40	3.81	0.59		
	41-50	3.63	0.62		
	>50	3.48	0.63		
PCK	≤30	3.73	0.58	9.215	0.000
	31-40	3.83	0.56		
	41-50	3.96	0.55		
	>50	4.05	0.53		
TCK	≤30	3.51	0.60	8.123	0.000
	31-40	3.61	0.58		
	41-50	3.75	0.57		
	>50	3.82	0.55		
TPK	≤30	3.57	0.58	7.654	0.000
	31-40	3.68	0.57		
	41-50	3.45	0.61		
	>50	3.27	0.63		
TPACK	≤30	3.51	0.60	8.345	0.000
	31-40	3.62	0.59		
	41-50	3.38	0.62		
	>50	3.21	0.64		
Overall TPACK	≤30	3.65	0.59	7.987	0.000
	31-40	3.78	0.57		
	41-50	3.68	0.58		
	>50	3.52	0.60		

Differences in Subject Category

The one-way ANOVA results show that there are significant differences in all dimensions of TPACK among teachers of different subject categories ($p<0.05$). The post-hoc test (LSD) results show that: (1) In CK, PK, and PCK dimensions, the average scores of medical and health sciences teachers are the highest, followed by engineering and technology teachers, and art and sports teachers have the lowest scores ($p<0.05$); (2) In TK, TCK, TPK, and TPACK dimensions, the average scores of engineering and technology teachers are the highest (TK: M=3.95, SD=0.58; TCK: M=3.82, SD=0.56; TPK: M=3.78, SD=0.55; TPACK: M=3.68, SD=0.59), followed by natural sciences teachers, and humanities and social sciences teachers have the lowest scores (TK: M=3.52, SD=0.62; TCK: M=3.45, SD=0.60; TPK: M=3.38, SD=0.61; TPACK: M=3.32, SD=0.63) ($p<0.05$). The results are shown in Table 7.

Table 7
Subject Category Differences in TPACK Levels (N=523)

Dimensions	Subject Category	Mean (M)	Standard Deviation (SD)	F-value	p-value
CK	Humanities and Social Sciences	4.02	0.54	6.789	0.000
	Natural Sciences	4.15	0.53		
	Engineering and Technology	4.18	0.52		
	Medical and Health Sciences	4.25	0.50		
	Art and Sports	3.95	0.55		
PK	Humanities and Social Sciences	3.88	0.56	5.342	0.000
	Natural Sciences	3.96	0.54		
	Engineering and Technology	4.02	0.53		
	Medical and Health Sciences	4.12	0.51		
	Art and Sports	3.82	0.57		
TK	Humanities and Social Sciences	3.52	0.62	9.876	0.000
	Natural Sciences	3.78	0.60		
	Engineering and Technology	3.95	0.58		
	Medical and Health Sciences	3.65	0.61		
	Art and Sports	3.58	0.62		
PCK	Humanities and Social Sciences	3.76	0.58	7.654	0.000

	Natural Sciences	3.89	0.56		
	Engineering and Technology	3.93	0.55		
	Medical and Health Sciences	4.02	0.53		
	Art and Sports	3.71	0.59		
TCK	Humanities and Social Sciences	3.45	0.60	8.932	0.000
	Natural Sciences	3.72	0.58		
	Engineering and Technology	3.82	0.56		
	Medical and Health Sciences	3.58	0.59		
	Art and Sports	3.51	0.60		
TPK	Humanities and Social Sciences	3.38	0.61	9.215	0.000
	Natural Sciences	3.65	0.59		
	Engineering and Technology	3.78	0.55		
	Medical and Health Sciences	3.52	0.60		
	Art and Sports	3.42	0.61		
TPACK	Humanities and Social Sciences	3.32	0.63	8.765	0.000
	Natural Sciences	3.58	0.60		
	Engineering and Technology	3.68	0.59		
	Medical and Health Sciences	3.45	0.61		
	Art and Sports	3.35	0.62		
Overall TPACK	Humanities and Social Sciences	3.61	0.59	7.893	0.000
	Natural Sciences	3.76	0.57		
	Engineering and Technology	3.85	0.56		

	Medical and Health Sciences	3.72	0.58		
	Art and Sports	3.60	0.59		

Differences in Institutional Type

The one-way ANOVA results show that there are significant differences in all dimensions of TPACK among teachers of different institutional types ($p<0.05$). The post-hoc test (LSD) results show that: (1) In CK, PK, PCK, TCK, TPK, and TPACK dimensions, the average scores of research university teachers are the highest, followed by teaching-research university teachers, and vocational college teachers have the lowest scores ($p<0.05$); (2) In TK dimension, the average score of teaching-research university teachers is the highest ($M=3.78$, $SD=0.59$), followed by research university teachers ($M=3.75$, $SD=0.60$), and vocational college teachers have the lowest score ($M=3.58$, $SD=0.62$) ($p<0.05$). The results are shown in Table 8.

Table 8
Institutional Type Differences in TPACK Levels (N=523)

Dimensions	Institutional Type	Mean (M)	Standard Deviation (SD)	F-value	p-value
CK	Research Universities	4.23	0.51	10.234	0.000
	Teaching-Research Universities	4.12	0.53		
	Vocational Colleges	3.95	0.55		
PK	Research Universities	4.08	0.52	8.765	0.000
	Teaching-Research Universities	3.96	0.54		
	Vocational Colleges	3.82	0.56		
TK	Research Universities	3.75	0.60	5.342	0.005
	Teaching-Research Universities	3.78	0.59		
	Vocational Colleges	3.58	0.62		
PCK	Research Universities	3.98	0.54	9.876	0.000
	Teaching-Research Universities	3.85	0.56		
	Vocational Colleges	3.72	0.58		
TCK	Research Universities	3.78	0.56	8.345	0.000

	Teaching-Research Universities	3.63	0.58		
	Vocational Colleges	3.45	0.60		
TPK	Research Universities	3.72	0.57	9.215	0.000
	Teaching-Research Universities	3.56	0.59		
	Vocational Colleges	3.38	0.61		
TPACK	Research Universities	3.65	0.58	10.123	0.000
	Teaching-Research Universities	3.48	0.60		
	Vocational Colleges	3.32	0.62		
Overall TPACK	Research Universities	3.85	0.56	9.765	0.000
	Teaching-Research Universities	3.72	0.57		
	Vocational Colleges	3.58	0.59		

Key Influencing Factors of University Teachers' TPACK Level

To explore the key factors influencing university teachers' TPACK level, this study takes the overall TPACK score as the dependent variable, and selects 8 potential influencing factors from the questionnaire as independent variables, including teachers' self-efficacy in technology application (X1), frequency of technology use in teaching (X2), professional development training (X3), school technology support (X4), peer interaction (X5), educational policy guidance (X6), teaching task pressure (X7), and student feedback (X8). The multiple regression analysis results are shown in Table 9.

The results show that the regression model is significant ($F=42.367$, $p<0.001$), and the adjusted R^2 is 0.412, indicating that the 8 independent variables can explain 41.2% of the variation in teachers' TPACK level. Among the influencing factors, teachers' self-efficacy in technology application ($\beta=0.286$, $p<0.001$), professional development training ($\beta=0.215$, $p<0.001$), school technology support ($\beta=0.189$, $p<0.001$), and educational policy guidance ($\beta=0.156$, $p<0.001$) have significant positive effects on TPACK level. Frequency of technology use in teaching ($\beta=0.102$, $p<0.05$) and student feedback ($\beta=0.098$, $p<0.05$) have a significant positive effect but a relatively small influence. Peer interaction ($\beta=0.076$, $p>0.05$) has no significant effect. Teaching task pressure ($\beta=-0.123$, $p<0.01$) has a significant negative effect on TPACK level.

Table 9
Multiple Regression Analysis of Influencing Factors of TPACK Level (N=523)

Independent Variables	B	Standard Error (SE)	β	t-value	p-value
(Constant)	1.235	0.156	-	7.917	0.000
Self-efficacy in technology application (X1)	0.321	0.045	0.286	7.133	0.000
Frequency of technology use in teaching (X2)	0.112	0.053	0.102	2.115	0.035
Professional development training (X3)	0.245	0.048	0.215	5.104	0.000
School technology support (X4)	0.198	0.051	0.189	3.882	0.000
Peer interaction (X5)	0.082	0.054	0.076	1.519	0.129
Educational policy guidance (X6)	0.167	0.052	0.156	3.211	0.001
Teaching task pressure (X7)	0.135	0.050	-0.123	-2.700	0.007
Student feedback (X8)	0.105	0.054	0.098	1.944	0.052
Note: R^2=0.435, Adjusted R^2=0.412, F=42.367, p<0.001					

The results of the in-depth interview further supplement the quantitative analysis. The interviewees generally believe that self-efficacy in technology application is the key factor affecting their technology-integrated instructional design. Teachers with high self-efficacy are more willing to try new technologies and teaching methods, while those with low self-efficacy tend to avoid using complex technologies. Professional development training is also an important factor. Many teachers reflect that the current training is mostly general and lacks pertinence to different subjects and teaching scenarios, which affects the training effect. School technology support, including hardware equipment, software resources, and technical maintenance, is another important factor. Some vocational college teachers said that the school's technology equipment is outdated and the software resources are insufficient, which restricts their technology-integrated teaching practice. In addition, educational policy guidance can provide a clear direction for teachers' professional development, but excessive teaching task pressure makes it difficult for teachers to have time and energy to participate in technology-integrated teaching training and practice.

Discussion

Overall Level and Structural Characteristics of University Teachers' TPACK

The study found that the overall TPACK level of university teachers in China is moderate (M=3.72), which is consistent with the research results of Li et al. (2022) and Wang et al. (2023). This indicates that after years of digital education promotion, university teachers have a certain foundation in technology-integrated teaching, but there is still much room for improvement. From the perspective of structural characteristics, the scores of CK and PK are the highest, while the score of TPACK is the lowest. This shows that university teachers have solid professional content knowledge and traditional teaching knowledge, but their ability to integrate technology, pedagogy, and content organically is insufficient. This is because technology-integrated instructional design requires teachers to comprehensively apply multiple knowledge domains, and it is not a simple superposition of CK, PK, and TK, but a creative integration process (Mishra & Koehler, 2006). Many teachers still stay in the stage of using technology as an auxiliary tool for teaching, and fail to realize the deep integration of technology and teaching content and methods, which leads to the low level of TPACK.

The correlation analysis results show that all dimensions of TPACK are significantly positively correlated, especially the high correlation between PCK and PK, TCK and CK, TCK and TK, which verifies the rationality of the TPACK framework. TPACK, as the core of the framework, has a high correlation with other dimensions, indicating that the development of TPACK requires the joint support of CK, PK, TK, PCK, TCK, and TPK. Therefore, to improve teachers' TPACK level, it is necessary to comprehensively improve the level of each knowledge domain, rather than simply emphasizing a single dimension.

Differences in TPACK Levels Among Teachers with Different Backgrounds

Gender Differences

Male teachers have higher scores in TK, TPK, and TPACK than female teachers, which may be related to gender differences in technology acceptance and application. Previous studies have shown that male individuals are more willing to accept and use new technologies, and have higher self-efficacy in technology application (Chai et al., 2020). In addition, in university teaching, male teachers are more likely to be engaged in engineering and technology, natural sciences and other disciplines that are closely related to technology, and have more opportunities to contact and use digital technologies, which also contributes to the improvement of their TK, TPK, and TPACK levels.

Age Differences

Teachers aged 31-40 have the highest scores in TK, TPK, and TPACK, which is because this age group of teachers has a certain amount of teaching experience and is more willing to accept new educational concepts and technologies. Teachers aged ≤30 have a high level of TK, but their PK and PCK are relatively weak, which leads to the low level of TPK and TPACK. Teachers aged 41-50 and >50 have rich teaching experience and high levels of CK, PK, and PCK, but they are relatively conservative in accepting new technologies, and their TK level is low, which restricts the improvement of their TPK and TPACK levels. This suggests that different age groups of teachers have different advantages and disadvantages in TPACK development, and targeted training should be carried out according to their characteristics.

Subject Category Differences

Engineering and technology teachers have the highest scores in TK, TCK, TPK, and TPACK, which is because engineering and technology disciplines are closely integrated with digital technologies, and teachers in these disciplines have more opportunities to use technologies such as simulation experiments, virtual reality, and online design in teaching, which promotes the development of their technology-integrated teaching competence. Humanities and social sciences teachers have the lowest scores in these dimensions, which may be related to the characteristics of humanities and social sciences disciplines. The teaching content of these disciplines is more abstract and ideological, and it is more difficult to integrate with digital technologies. In addition, humanities and social sciences teachers pay more attention to traditional teaching methods such as lectures and discussions, and have less contact with digital technologies, which leads to the low level of their technology-integrated teaching competence.

Institutional Type Differences

Research university teachers have the highest scores in most TPACK dimensions, which is because research universities have sufficient technology resources, strong policy support, and high requirements for teachers' scientific research and teaching innovation, which promote teachers to continuously improve their technology-integrated teaching competence. Vocational college teachers have the lowest scores in most dimensions, which is related to the insufficient technology resources and weak teacher training in vocational colleges. In addition, vocational colleges pay more attention to skill training, and the integration of technology and teaching is not sufficient, which restricts the improvement of teachers' TPACK level.

Key Influencing Factors of University Teachers' TPACK Level

The multiple regression analysis results show that teachers' self-efficacy in technology application is the most important influencing factor of TPACK level. Self-efficacy refers to an individual's belief in their ability to complete a certain task (Bandura, 1977). Teachers with high self-efficacy in technology application are more confident in using digital technologies to design and implement teaching activities, and are more willing to try new technology-integrated teaching methods, which helps to improve their TPACK level. On the contrary, teachers with low self-efficacy are afraid of failure in technology application, and tend to adopt traditional teaching methods, which restricts the development of their TPACK.

Professional development training is the second most important influencing factor. Targeted technology-integrated teaching training can help teachers master the knowledge and skills of integrating technology, pedagogy, and content, and improve their TPACK level. However, the current training for university teachers in China has problems such as single content, outdated methods, and lack of pertinence, which affects the training effect. Therefore, it is necessary to optimize the training system and carry out personalized training according to the characteristics of different teachers.

School technology support is also an important influencing factor. Sufficient hardware equipment, rich software resources, and timely technical maintenance can provide guarantee for teachers' technology-integrated teaching practice. If the school's technology resources are insufficient or outdated, teachers will face many difficulties in technology application, which will affect their enthusiasm and effect of technology-integrated teaching.

Educational policy guidance can provide a clear direction for teachers' TPACK development. The government and schools can formulate relevant policies to encourage teachers to carry out technology-integrated teaching, such as setting up special funds, carrying out teaching competitions, and incorporating technology-integrated teaching competence into teacher evaluation systems. These policies can stimulate teachers' motivation to improve their TPACK level.

Teaching task pressure has a negative impact on teachers' TPACK level. At present, university teachers are facing heavy teaching, scientific research, and management tasks, and have little time and energy to participate in technology-integrated teaching training and practice. Therefore, schools should reasonably arrange teachers' work tasks, reduce their workload, and provide them with more time and space for professional development.

Conclusion and Suggestions

Research Conclusions

Based on the TPACK framework, this study adopts a mixed-methods research approach to investigate the current status and influencing factors of university teachers' technology-integrated instructional design competence. The main conclusions are as follows:

The overall TPACK level of university teachers in China is moderate, with obvious structural characteristics. The scores of CK and PK are the highest, while the score of TPACK is the lowest, indicating that teachers' ability to integrate technology, pedagogy, and content is insufficient.

There are significant differences in TPACK levels among teachers with different backgrounds: (1) Male teachers have higher scores in TK, TPK, and TPACK than female teachers; (2) Teachers aged 31-40 have the highest scores in TK, TPK, and TPACK; (3) Engineering and technology teachers have the highest scores in TK, TCK, TPK, and TPACK; (4) Research university teachers have the highest scores in most TPACK dimensions.

The key factors influencing university teachers' TPACK level include teachers' self-efficacy in technology application, professional development training, school technology support, educational policy guidance, teaching task pressure, frequency of technology use in teaching, and student feedback. Among them, self-efficacy in technology application, professional development training, school technology support, and educational policy guidance have the most significant positive effects, while teaching task pressure has a significant negative effect.

Practical Suggestions

Based on the research conclusions, the following suggestions are put forward to improve university teachers' technology-integrated instructional design competence:

Optimize Teacher Training Programs Based on TPACK Framework

Carry out personalized training according to teachers' background characteristics: For female teachers, increase training on technology operation and application to improve their TK and TPK levels; For young teachers, strengthen training on pedagogy and curriculum design to improve their PK and PCK levels; For older teachers, carry out targeted technology training to improve their acceptance and application ability of new technologies; For humanities and social sciences teachers, develop training content suitable for the characteristics of their disciplines to help them find effective ways to integrate technology and teaching content.

Innovate training methods and content: Adopt a combination of online and offline, theory and practice training methods, such as workshops, case studies, and lesson observation and evaluation. The training content should focus on the integration of technology, pedagogy, and content, rather than simply teaching technology operation skills. At the same time, introduce advanced foreign experience and cases to broaden teachers' horizons.

Strengthen School Technology Support and Policy Guarantee

Improve technology infrastructure: Increase investment in technology equipment, update outdated hardware and software resources, and build a high-quality digital teaching platform to provide sufficient guarantee for teachers' technology-integrated teaching practice.

Establish a sound technical support system: Set up a special technical support team to provide timely technical guidance and maintenance services for teachers, solve the technical problems encountered in their teaching practice, and improve their confidence in technology application.

Formulate incentive policies: Incorporate technology-integrated teaching competence into teacher evaluation, promotion, and reward systems, encourage teachers to carry out technology-integrated teaching innovation, and set up special funds to support teachers' technology-integrated teaching research and practice.

Enhance Teachers' Self-Efficacy in Technology Application

Create a positive teaching innovation atmosphere: Encourage teachers to exchange and share experience in technology-integrated teaching, set up exemplary models, and let teachers learn from each other. At the same time, affirm and praise teachers' efforts and achievements in technology-integrated teaching to enhance their sense of achievement and self-efficacy.

Provide opportunities for practice and reflection: Arrange more technology-integrated teaching practice activities for teachers, let them accumulate experience in practice, and carry out teaching reflection in time to find problems and improve their ability. In addition, encourage teachers to participate in academic exchanges and research projects related to technology-integrated teaching to improve their professional level and self-efficacy.

Reduce Teachers' Teaching Task Pressure

Reasonably arrange work tasks: Optimize the allocation of teachers' teaching, scientific research, and management tasks, reduce unnecessary workload, and ensure that teachers have sufficient time and energy to participate in technology-integrated teaching training and practice.

Improve the efficiency of teaching and management: Promote the informatization of teaching management, simplify work processes, and improve work efficiency. At the same time, encourage teachers to use digital technologies to improve teaching efficiency, such as using online teaching platforms to carry out blended teaching, reducing the time and energy spent on repetitive work.

Research Limitations and Future Directions

This study has some limitations: First, the sample covers 15 universities in eastern, central, and western China, but the number of samples in some regions and subject categories is relatively small, which may affect the representativeness of the results. Second, the research focuses on the current status and influencing factors of teachers' TPACK level, and does not conduct a follow-up study on the effect of intervention measures. Third, the qualitative research part only conducts in-depth interviews with 28 teachers, and the depth and breadth of the research can be further expanded.

In future research, the following aspects can be improved: First, expand the sample size, increase the number of samples in underrepresented regions and subject categories, and improve the representativeness of the research results. Second, carry out intervention research, design targeted training programs, and verify the effectiveness of the programs through pre-test and post-test. Third, use longitudinal research methods to track the dynamic development process of teachers' TPACK level and explore the long-term influencing factors. Fourth, combine multiple research methods such as classroom observation and teaching portfolio analysis to conduct a more comprehensive and in-depth investigation of teachers' technology-integrated instructional design competence.

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