

Research on the Development of Digital and Intelligent Teaching Skills of Design Teachers in Universities under the I-TPACK Framework

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Abstract: The rapid development of artificial intelligence technology is profoundly reshaping the knowledge production and talent cultivation models in design education. The digital teaching capabilities of teachers directly affect the effectiveness of the digital transformation in design education. This study, based on the Intelligent-TPACK (I-TPACK) theoretical framework proposed by Celik (2023), uses a questionnaire survey method to conduct an empirical study on 286 design education teachers from 23 universities across the country. The study adopts the I-TPACK mature scale adapted to the design context (27 items, 5-point Likert scoring), which is verified by confirmatory factor analysis (CFA). The scale's combined reliability CR ranges from 0.86 to 0.90, and the Cronbach's α coefficient ranges from 0.859 to 0.900, demonstrating good reliability and validity. The study employs descriptive statistics, one-way ANOVA, and Pearson correlation analysis for data processing. The results show: 1) The overall I-TPACK ability of design education teachers is at a moderately high level, but there is a significant structural imbalance. The technical knowledge dimension (TK) has the highest score ($M=3.91$), while the ethical assessment dimension (Ethics) has the lowest score ($M=3.15$); 2) There are significant differences in teacher quality levels between teaching experience and academic title. The technical knowledge of the group with 0–3 years of teaching experience is significantly higher than that of the group with more than 20 years, and the professor group performs best in the teaching method knowledge dimension; 3) There are significant differences in AI ethics dimensions among institutions of higher learning. Teachers from independent art colleges have the highest ethical cognition level; 4) There is a significant positive correlation among the five dimensions of I-TPACK, but the correlation between technical knowledge and ethical assessment is relatively weak ($r=0.447$). The study believes that the digital transformation of design education requires the establishment of a stratified empowerment precision training system, elevating ethical education to a core module, and emphasizing the leading role of the teacher group in the professional maturity stage. [PAN Husheng, LIU Xueqi. **Research on the Development of Digital and Intelligent Teaching Skills of Design Teachers in Universities under the I-TPACK Framework**. *Nat Sci* 2026,24(9):49-56]. ISSN 1545-0740 (print); ISSN 2375-7167 (online). <http://www.sciencepub.net/nature> 07. doi:[10.7537/marsnsj240926.07](https://doi.org/10.7537/marsnsj240926.07)

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1. Introduction

The rapid development of artificial intelligence technology is leading to profound changes in the education sector. The emergence of generative artificial intelligence tools has brought unprecedented opportunities and challenges to teaching design, learning evaluation, and knowledge production. In 2018, the Ministry of Education first proposed the concept of teacher intelligent education literacy in the "Notice on Carrying out Pilot Work for the Promotion of Teacher Team Building by Artificial Intelligence", clearly stating that teachers should be guided to actively apply artificial intelligence technology and build educational scenarios that combine digital and intelligent elements. In 2019, the UNESCO released "Artificial Intelligence in Education: Opportunities and Challenges for Sustainable Development", pointing out that teachers need to be prepared in both directions, including mastering the application ability of AI technology and paying attention to ethical issues such as data privacy and algorithm fairness. In 2024, the UNESCO further released the "Teacher AI Competence Framework", taking human-centered AI thinking, AI ethics, and AI and teaching methods as the core elements of teachers' AI literacy. In 2026, the Ministry of Education of China and five other departments issued the "Artificial Intelligence + Education Action Plan", officially proposing a new model of educational development based on human-machine collaboration. The intensive introduction of these policy measures marks that the digital and intelligent teaching capabilities of teachers have risen from an academic topic to a core concern in global education strategies.

Teachers, as the direct subjects of educational practice, undertake threefold missions: knowledge dissemination, ability cultivation, and value guidance. The deep integration of artificial intelligence technology with the aforementioned educational goals objectively requires a systematic reconfiguration of teachers' professional roles and functions, and the establishment of an intelligent education literacy cultivation mechanism that is compatible with it. Among various theoretical frameworks, Celik (2023) proposed the Intelligent-TPACK (I-TPACK) framework, which provides an integrated analytical tool for understanding teachers' AI-related literacy. This framework expands on the classic TPACK based on the technical characteristics of generative AI, adding an ethical assessment dimension, enabling the measurement of teachers' literacy to extend from technical operational ability to ethical judgment and value guidance ability, providing a more complete theoretical framework for the assessment of teachers' capabilities in the AI era. However, existing studies show that the development of teachers' digital and intelligent teaching capabilities generally lags behind the speed of technological iteration. Karaduman and Akman (2024) pointed out in a comprehensive review of TPACK literature that most teachers remain at the surface stage of using tools, lacking the knowledge framework and teaching design ability to integrate technology deeply into subject teaching.

More critically, existing research on human-machine collaborative teacher digital and intelligent literacy mostly focuses on basic education or general educational scenarios, and rarely conducts empirical investigations on the discipline group of design education. Design education has distinct characteristics that are different from other disciplines: on the one hand, design thinking emphasizes creative divergence, prototype iteration, and critical evaluation, and the intervention of AI tools brings unique adaptability challenges and integration opportunities for these teaching links; on the other hand, the design discipline's high reliance on originality and aesthetic judgment requires teachers to handle more complex ethical issues when facing AIGC technology. Based on this, this study uses the I-TPACK theory as an analytical framework and focuses on the following core research questions: 1) What is the overall development status and characteristics of the digital and intelligent teaching capabilities of teachers in design-related universities? 2) What are the differences in digital and intelligent teaching capabilities among different demographic groups (tenure, professional title, institution type, discipline direction)?

2. Literature Review and Theoretical Framework

2.1 From TPACK to I-TPACK: The Theoretical Evolution of Teachers' Digital and Intelligent Literacy

The TPACK (Technological Pedagogical Content Knowledge) framework was proposed by Mishra and Koehler in 2006, marking a shift from fragmented exploration of technology integration in teacher knowledge research to systematic theoretical construction. The core proposition of this framework is that teacher knowledge is not a simple combination of content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK), but rather a five-component complex knowledge formed through the intersection and integration of these three aspects, namely, subject teaching knowledge (PCK), integrated technological subject content knowledge (TCK), integrated technological pedagogical knowledge (TPK), and integrated technological subject teaching knowledge (TPACK) (Koehler & Mishra, 2009). This framework breaks through previous research's limitations in integrating technology, pedagogy, and content knowledge, providing a systematic analytical perspective for understanding how teachers effectively integrate technology into teaching practice. Since then, the TPACK framework has been widely verified and applied globally, becoming one of the most influential theoretical models in the field of teacher technology integration research (Chai et al., 2013). However, with the rapid iteration of artificial intelligence technology, the traditional TPACK framework faces new challenges in explanatory power: the black box nature of generative AI, the potential risks of algorithm bias, and the ethical controversies of AI-generated content, all of which require teachers to develop independent ethical assessment capabilities beyond technical and pedagogical wisdom.

To respond to this theoretical need, Celik (2023) developed the Intelligent-TPACK (I-TPACK) scale, which verified the five-factor structure through empirical research on 428 teachers and found that ethical assessment has a significant predictive effect on TPACK ($\beta = 0.42, p < 0.001$). The theoretical contributions of this framework are threefold: First, it redefines technological knowledge as a comprehensive ability covering the operation of AI tools, the cognitive understanding of AI principles, and the judgment of AI development trends, breaking through the narrow understanding of traditional TK dimensions as general information technology; while retaining the classic TPACK integration knowledge, it adds an ethical assessment dimension, specifically measuring teachers' ethical sensitivity, value guidance ability, and responsible use awareness in AI-assisted teaching, expanding the measurement of teacher 素养 from technical ability to ethical judgment and value guidance; then it emphasizes that teachers need to understand the training mechanism, capacity range, and potential biases of AI models, formally incorporating generative AI literacy into the components of the teacher knowledge structure. This theoretical expansion provides a more precise measurement framework for designing the assessment of teachers' subject teaching abilities, as designing teachers not only need to master the operational skills of AI tools but also need to handle the tension between

creative protection and technological innovation in guiding students to use AI.

In the Chinese local context, researchers have also conducted exploratory studies on teachers' digitalization and intelligence literacy. Wang Dan (2022) proposed that in the intelligent era, teachers need to possess intelligent education literacy that integrates technology, education, and society, covering six core elements: technical cognition, innovative teaching, human-machine collaboration, resource integration, data application, and ethical security. Yang Xu (2022) based on the local context constructed an integrated subject teaching knowledge framework for intelligent technology (I-TPACK), incorporating learner knowledge and contextual knowledge into the structural system, and confirming through the analysis of 2,269 questionnaires and 80 smart classroom videos that integrated knowledge is the key dimension that distinguishes novice teachers from expert teachers. Zhu Zhiting (2018) from the perspective of smart education emphasized that teacher development needs to go beyond surface-level training focused on technical operations and shift towards deep capacity building centered on data intelligence. However, the above research has not yet conducted contextual transfer for the design discipline, which emphasizes creative practice, aesthetic judgment, and ethical reflection. The unique predicaments and capacity demands of design teachers in the digital and intelligent transformation still need to be further explored.

2.2 The uniqueness of the digital and intelligent literacy of teachers in the design field

Design education possesses distinct disciplinary characteristics that set it apart from other forms of higher education. Firstly, design thinking not only emphasizes logical reasoning and operational norms, but also places greater emphasis on acquiring knowledge through practice and reflection. This experiential learning cognitive model makes design teaching highly dependent on immediate interaction between teachers and students. Secondly, the art design discipline inherently has a cross-disciplinary attribute. As design studies are officially incorporated into the category of interdisciplinary disciplines, constructing a diverse and rich teaching content and methodology system has become the key path to resolving the current predicament of design education. From the perspective of teaching practice, user research, creative divergence, prototype iteration, and critical evaluation constitute the core components of design education. The intervention of AI tools precisely brings unique adaptability challenges to these aspects. However, whether AI can replace the empathetic ability in design thinking and the understanding of cultural contexts in visual communication, these issues highlight the particularity of the digital and intelligent literacy of design education teachers.

Van der Burg et al. (2026) specifically pointed out in their research on reflective AI in design disciplines that in the context of creative-intensive design education, the efficiency-driven use model of AI may undermine the core reflective practice of design education. They advocate transforming AI from a black box that quickly outputs results into a tool that helps students reflect on the design process through means of material deconstruction and time deconstruction. This implies that the I-TPACK literacy of design education teachers should include two special tension dimensions: one is the protection of creativity and the openness of technology: while guiding students to use AI to expand creative possibilities, it is also necessary to protect the original design thinking from being overly eroded by algorithmic thinking; the other is the cultivation of reflective practice ability: teachers need to possess the ability to conduct design reflection, allowing students to identify the limitations and potential of AI output. However, existing research on design education mostly focuses on the dimension of student ability development, and empirical research on teachers' professional literacy is still relatively weak. Liu Bangqi and Yuan Tingting (2019) constructed the overall architecture of an intelligent education system, but did not deeply address the issue of the knowledge structure of design discipline teachers; Peng Yulan (2022) proposed the AI-TPACK framework, which points to teaching knowledge in the field of artificial intelligence, but failed to fully respond to deep issues such as copyright ownership of AIGC and controversies over originality in style transfer in design ethics. Therefore, this study selects the I-TPACK five-dimensional model as the core theoretical tool to conduct a systematic assessment of the digital and intelligent teaching ability of design education teachers, which has clear disciplinary relevance and theoretical necessity.

3. Research Design

3.1 Research subjects and sampling strategy

This study employed a stratified purposive sampling strategy, adhering to the principle of maximizing the variation in institutional level, discipline direction, and teaching experience of teachers. In terms of selecting institutions, it covered 23 universities across the country that offer design-related majors, including 13 universities under the "Double First-Class" program, 5 independent art colleges, 3 design colleges of comprehensive universities, and 2 vocational colleges, distributed in the five major regions of North China, East China, South China, Southwest China, and Northwest China, to ensure the geographical representativeness of the sample. Within each institution, it was stratified by five directions: visual communication design, environmental design, product design, digital media art, and clothing and apparel design, to ensure the coverage of disciplines. Within each direction, electronic questionnaires were

distributed by stratifying by teaching experience on the Questionnaire Star platform, and a total of 308 responses were collected. After excluding invalid questionnaires with response times less than 3 minutes, 286 valid questionnaires were obtained, with an effective rate of 92.86%. The demographic characteristics of the sample are shown in Table 1: The gender distribution is relatively balanced (51.0% females, 49.0% males); the age range is mainly 30–50 years old (accounting for 63.7%); the teaching experience distribution covers the complete career spectrum from novice to senior teachers; the professional title structure is mainly lecturers (53.1%), assistant teachers, associate professors, and professors account for 9.1%, 30.4%, and 7.3% respectively; the type of institutions is mainly ordinary undergraduate universities (49.3%), "Double First-Class" program universities, independent art colleges, and vocational colleges account for 13.3%, 12.2%, and 25.2% respectively; in terms of the frequency of using AI tools, over 45% of teachers use AI tools more than three times a week, indicating a high level of technical exposure.

Table 1. Demographic Characteristics of the Sample (N = 286)

Variables	Category	Frequency (n)	Percentage (%)
Gender	Female	146	51.0
	Man	140	49.0
Teaching Experience	0–3 years	54	18.9
	3–10 years	86	30.1
	10–20 years	70	24.5
	Over 20 years old	76	26.6
Title	Teaching Assistant	26	9.1
	Lecturer	152	53.1
	Associate Professor	87	30.4
	Professor	21	7.3
University types	Double First-Class Universities	38	13.3
	General undergraduate institutions	141	49.3
	Independent Fine Arts College	35	12.2
	Vocational Schools	72	25.2

3.2 Data analysis methods

The data analysis was conducted using SPSS 29.0 and AMOS 29.0. Firstly, descriptive statistical analysis was employed to calculate indicators such as the mean, standard deviation, skewness, and kurtosis of each dimension, presenting an overall picture of the I-TPACK capabilities of design teachers. Secondly, confirmatory factor analysis (CFA) was used to test the structural validity of the scale, evaluating the model fit indices (χ^2/df , RMSEA, CFI, TLI, IFI) as well as the composite reliability (CR) and average variance extracted (AVE) of each dimension. Thirdly, one-way ANOVA was used to explore the differences in each dimension of I-TPACK among teachers with different teaching years, titles, institution types, and subject directions. Finally, Pearson correlation analysis was used to explore the internal correlations among the five dimensions of I-TPACK, and partial correlation analysis was used to control the influence of statistical variables of individuals.

4. Research results

4.1 Descriptive statistics and validity and reliability tests

The descriptive statistical results (see Table 2) show that the I-TPACK capabilities of design teachers exhibit a significant structural differentiation feature. The technical knowledge dimension (TK) has the highest score ($M = 3.91$, $SD = 0.57$), indicating that teachers have a good grasp of the basic operations of AI design tools; the technology-teaching method integration dimension (TPK) follows ($M = 3.54$, $SD = 0.55$), suggesting that teachers have initially acquired the ability to integrate AI into teaching design; the technology-subject content integration dimension (TCK) is in the middle ($M = 3.49$, $SD = 0.51$), reflecting that teachers can utilize AI to search for cutting-edge resources in the subject field; while the TPACK dimension, which represents the highest-order integration ability, has a relatively low score ($M = 3.45$, $SD = 0.58$), indicating that teachers still have considerable room for improvement in their ability to comprehensively apply technology, teaching methods, and subject content knowledge in real teaching scenarios. Particularly notable is the ethics dimension (Ethics), with an average score of the lowest among all five dimensions ($M = 3.15$, $SD = 0.63$), reflecting that the current group of design teachers has significant shortcomings in terms of AI ethical sensitivity, value guidance ability, and responsible use awareness. The absolute values of skewness for all five dimensions are less than 2, and the absolute values of kurtosis are less than 7, indicating that the data distribution basically conforms to the normality assumption and meets the prerequisite conditions for parametric tests. The standard deviations of each dimension range from 0.51 to 0.63, suggesting that there is some heterogeneity within the

sample, providing a basis for subsequent group difference analysis.

Table 2. Descriptive Statistical Results of Each Dimension of I-TPACK

Dimension	N	Minimum value	Maximum value	Mean (M)	Standard Deviation (SD)	Skewness	Kurtosis
TK	286	2.40	5.00	3.91	0.57	-0.233	-0.632
TPK	286	1.86	4.86	3.54	0.55	0.038	-0.099
TCK	286	2.50	5.00	3.49	0.51	0.212	-0.433
TPACK	286	1.86	4.86	3.45	0.58	-0.229	-0.303
Ethics	286	1.50	5.00	3.15	0.63	0.111	-0.118

The results of confirmatory factor analysis showed that the five-factor model fit well: $\chi^2/df = 1.737 (< 3)$, RMSEA = 0.051 (< 0.08), RMR = 0.030 (< 0.08), CFI = 0.949, TLI = 0.943, IFI = 0.949 (all > 0.90), all indicators met or approached the recommended standards, indicating that the scale has good structural validity. In terms of reliability testing, the Cronbach's α coefficients of each dimension ranged from 0.859 to 0.900, and the overall reliability coefficient was 0.946; the composite reliability (CR) ranged from 0.860 to 0.900, and the average variance extracted (AVE) ranged from 0.532 to 0.684, all meeting the discriminant criteria of $CR > 0.70$ and $AVE > 0.50$ (see Table 3). The KMO value was 0.936 (> 0.90), the approximate chi-square value of Bartlett's spherical test was 4724.796 ($df = 351$, $p < 0.001$), indicating that the data are extremely suitable for factor analysis. The above results fully demonstrate that the I-TPACK scale adapted to the design learning context has good reliability and validity, and can be used as a reliable measurement tool for the core variable of this study.

Table 3. Results of Scale Validity and Reliability Testing

Dimension	Item count	Cronbachs α	CR	AVE
TK	5	0.859	0.860	0.552
TPK	6	0.888	0.888	0.532
TCK	6	0.895	0.896	0.684
TPACK	6	0.900	0.900	0.563
Ethics	4	0.886	0.885	0.658
Overall	27	0.946	—	—

4.2 Analysis of the differences in demographic variables

The results of the one-way analysis of variance showed that teaching experience had a significant impact on the technical knowledge dimension (TK) ($F = 7.224$, $p < 0.001$). The LSD post-hoc multiple comparisons revealed (see Table 4) that the group with 0–3 years of teaching experience ($M = 4.13$) and the group with 3–10 years of teaching experience ($M = 3.98$) were significantly higher than the group with 20–30 years of teaching experience ($M = 3.70$) and the group with more than 30 years of teaching experience ($M = 3.28$) in TK, presenting a clear generational difference between digital natives and digital immigrants. Young teachers grew up in a digital environment and have a faster acceptance and learning speed of emerging AI tools, thus having a natural advantage in technical operation. However, it is worth noting that the group with 10–20 years of teaching experience ($M = 3.81$) was slightly lower than the novice group in TK, but performed better than other groups in the TPACK dimension, indicating that rich teaching experience can partially compensate for the lack of technical ability and achieve human-machine collaborative teaching through the effective application of teaching wisdom. The 职称 analysis showed that the technical knowledge dimension showed a significant downward trend with the increase in professional title ($F = 9.392$, $p < 0.001$), with the teaching assistant having the highest score ($M = 4.26$) and the professor having the lowest score ($M = 3.59$), reflecting the agility advantage of teachers with lower professional titles in pure technical operation. In contrast, the teaching method knowledge dimension (TPK) showed the opposite trend ($F = 3.914$, $p = 0.009$), with the professor group having the highest score ($M = 3.86$) and the teaching assistant having the lowest score ($M = 3.37$), confirming that high-professional-title teachers have an advantage in AI teaching integration with their profound teaching accumulation. The TPACK ability of the full professor group was lower than that of the associate professor, which may be related to the administrative burden effect. Full professors often undertake more disciplinary management and social service responsibilities, and have limited time and energy available for following technological frontiers and innovating teaching.

Table 4. Results of One-Way ANOVA Based on Teaching Experience and Professional Title

Variable	Group	n	Mean (M)	Standard Deviation (SD)	F	p
TK	0–3 years	54	4.13	0.65	7.224	<0.001
	3–10 years	86	3.98	0.65		
	10–20 years	70	3.81	0.73		
	20–30 years	56	3.70	0.72		
	More than 30 years	20	3.28	0.69		
TPK	Teaching Assistant	26	3.37	0.81	3.914	0.009
	Lecturer	152	3.42	0.76		
	Associate	87	3.67	0.71		
	Professor					
	Professor	21	3.86	0.64		

The analysis of institution types reveals an enlightening finding: there are significant differences in the AI ethics dimension ($F=3.064$, $p=0.028$, see Table 5). The ethical cognitive level of independent art college teachers is the highest ($M=3.44$), followed by vocational colleges ($M=3.25$), ordinary undergraduate colleges rank third ($M=3.06$), while the double-first-class construction universities with the most abundant resources are the lowest ($M=2.96$). This result strongly challenges the resource assumption, which holds that the differences in technical capabilities are mainly determined by hardware resources and funding investment. The data indicate that although key institutions have significant advantages in the accessibility of technical tools and the frequency of training, this hardware-level lead does not automatically translate into an advantage in high-level ethical literacy. One possible explanation is that independent art colleges and vocational colleges, due to facing more prominent employment orientation and market competition pressure, teachers pay more attention to the impact of AI technology on students' employment ability and creative core competitiveness, thus having a higher sensitivity to AI ethics issues. The discipline directions did not reach statistical significance in all dimensions ($p>0.05$), indicating that teachers in different professional directions such as visual communication design, environmental design, and product design tend to be consistent in their digital and intelligent teaching capabilities, and discipline direction is not a key factor affecting I-TPACK capabilities.

Table 5. Results of One-Way ANOVA Based on Institution Type

Dimension	University Type	n	Mean (M)	Standard Deviation (SD)	F	p
AI Ethics	Double First-Class Universities	38	2.96	0.75	3.064	0.028
	General undergraduate institutions	141	3.06	0.78		
	Independent art colleges	35	3.44	0.94		
	Vocational colleges	72	3.25	0.84		

4.3 Correlation analysis among the various dimensions of I-TPACK

The Pearson correlation analysis results (see Table 6) show that there is a significant positive correlation among the five dimensions of I-TPACK ($p < 0.01$), with correlation coefficients ranging from 0.447 to 0.636, indicating that the five dimensions are both relatively independent and interrelated, collectively forming an organic whole of teachers' digitalized teaching capabilities. Specifically, the correlation between TCK and the TPK dimension is the strongest ($r = 0.636$, $p < 0.01$), suggesting that a deep understanding of subject content knowledge is conducive to enhancing the ability to integrate teaching methods and technologies. Teaching method knowledge serves as the core foundation for high-level teaching integration. The correlation between ethical assessment and the TPK dimension is the second strongest ($r = 0.567$, $p < 0.01$), indicating that teachers with stronger ethical sensitivity are more cautious and comprehensive when integrating AI technology, and can actively design ethical discussion sessions in teaching to guide students to establish a critical human-machine collaborative concept. The correlation between TK and TCK is also relatively close ($r = 0.555$, $p < 0.01$), reflecting that the improvement of technical ability helps expand the breadth and depth of subject content acquisition. It is noteworthy that the correlation between TK and ethical assessment is relatively the weakest among the five pairs of dimensions ($r = 0.447$, $p < 0.01$), and the partial correlation coefficient remains 0.447 after controlling for variables such as education level and professional title, indicating that there is a relatively independent development path between technical ability and ethical literacy. This finding has important theoretical and practical implications: it challenges the traditional view of regarding ethics as the natural extension or

additional attribute of technical ability, revealing the independent status and significant value of ethical reflection ability in the teacher's digitalized teaching capability system. In other words, the improvement of technical operational ability does not automatically lead to an increase in ethical sensitivity; ethical literacy requires specialized training and systematic education to develop effectively. This finding is in strong agreement with Celik (2023)'s core positioning of the ethical dimension in the I-TPACK framework and provides empirical evidence for the training strategy of prioritizing ethics proposed in this study.

Table 6. Pearson Correlation Matrix of the Five Dimensions of I-TPACK (** $p < 0.01$)

Variable	TK	TPK	TCK	TPACK	Ethics
TK	1				
TPK	0.528**	1			
TCK	0.555**	0.573**	1		
TPACK	0.474**	0.636**	0.559**	1	
Ethics	0.447**	0.567**	0.507**	0.489**	1

5. Conclusions and Recommendations

5.1 Research conclusion

This study, based on the I-TPACK theoretical framework, conducted a systematic assessment of the digital and intelligent teaching abilities of 286 design teachers in universities. The main conclusions are as follows: 1) The overall I-TPACK ability of design teachers in Chinese universities is at a moderately high level (the mean values of each dimension range from 3.15 to 3.91), but there is a structural imbalance where the technical knowledge dimension is significantly advanced and the ethical assessment dimension is significantly lagging behind. The differences are highly statistically significant, reflecting the current ability gap of the teacher group, which is strong in technology but weak in ethics. 2) Teaching experience and professional title have a significant impact on I-TPACK ability. Teachers with 11–20 years of teaching experience have a significantly higher TPACK level than other groups, reflecting the optimal balance between experience accumulation and technology adaptation in mature teaching careers. The professor group performs best in teaching method knowledge dimension, but the technical knowledge dimension decreases with the increase in professional title, revealing the restrictive effect of administrative burden on the technical follow-up of senior teachers. 3) There are significant differences in the AI ethics dimension among different types of institutions. Teachers from independent art colleges and vocational schools have significantly higher ethical cognition levels than those from top universities, challenging the resource determinism hypothesis. It indicates that the cultivation of advanced ethical literacy requires more than just hardware investment, and focuses on the update of teaching concepts and institutional design. 4) There is a significant positive correlation among the five dimensions of I-TPACK, but the association between technical knowledge and ethical assessment is relatively weak and remains independent. This reveals that ethical literacy requires specialized cultivation rather than being naturally attached to the improvement process of technical ability.

5.2 Solutions and suggestions

Based on the above research findings, this study proposes the following countermeasures and suggestions. Firstly, implement a teacher training system that is stratified and enables targeted measures. Design differentiated training programs for teachers of different teaching experience, professional titles, and educational institutions: for young teachers, focus on enhancing their ability to integrate teaching, helping them transform their technical operational advantages into teaching design wisdom; for teachers in the professional maturity stage, assign them leading roles and utilize their bridging role in intergenerational collaboration; for senior professor groups, reduce their administrative burdens and provide them with time conditions for teaching innovation. Secondly, establish industry norms for the digitalization of design education that prioritize ethics. Universities should collaborate with design industry associations to formulate AIGC design teaching ethics guidelines, clearly defining the boundaries of AI tools' availability, attribution norms, and evaluation weights at different course stages; given the pivotal role of ethical assessment dimensions and the widespread weakness, it is recommended to incorporate the AI ethics education module into the compulsory content of teacher training instead of as an elective supplement. Finally, reform the teacher evaluation system, incorporate AI teaching innovation into the weight of professional title evaluation and performance assessment, reversing the misalignment of incentives that prioritize research over teaching; at the same time, establish a design education AI teaching research community across universities to break the dilemma of isolated teacher exploration and promote experience sharing and collaborative innovation.

5.3 Research Limitations and Prospects

This study has the following limitations. Firstly, it is unable to reveal the dynamic development trajectory of teachers'

I-TPACK capabilities. In the future, a longitudinal tracking design can be adopted, combined with classroom observations and analysis of teaching videos, to further depict the development path of design school teachers from novice to expert. Secondly, although the sample covers five regions and various types of institutions, 286 questionnaires are still insufficient for revealing the complex interaction effects of demographic statistics. Future research can consider increasing the sample size and introducing multilevel linear models (HLM) for multilevel analysis at the institutional and individual levels. Thirdly, this study mainly relies on teachers' self-reported reports, which may have social expectation biases. In the future, it can be combined with multiple data sources such as student evaluations, peer reviews, and classroom observations for verification.

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