



A model for building a blended learning environment based on the TPACK framework to support teaching competence in higher education

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SUMMARY: *In the deepening digital transformation of education, teachers' digital teaching competencies have become a key indicator influencing their overall capabilities and a core driver for enhancing teaching quality in this educational shift. This paper constructs a framework for cultivating teachers' blended teaching design capabilities—both online and offline—based on the TPACK framework and considering the context of teachers operating in hybrid learning environments. It summarizes four pathways for improvement. Using random sampling surveys, data related to teachers' information-based teaching competencies were collected and analyzed with statistical tools. The average score for the seven TPACK components was 3.3065, with a standard deviation of 0.5486. The overall TPACK value exceeded the theoretical median, indicating teachers possess relatively strong capabilities in integrating technological knowledge with subject-specific pedagogical knowledge. Linear regression analysis revealed a regression coefficient of 0.5495 for TPK on TPACK, with a *t*-value of 7.5486 and $P=0.00<0.01$. This indicates that TPK exerts a significant positive influence on TPACK, meaning the integration of technological pedagogical content knowledge notably elevates the overall TPACK level. Additionally, teachers with teaching practicum experience had an average TPACK total score of 3.5419, higher than the 3.3214 average of those without such experience. Participating in teaching practicums significantly enhances teachers' overall TPACK proficiency.*

KEYWORDS: *TPACK; blended learning environment; statistical data analysis; information-based teaching competency*

1 Introduction

In the deepening digital transformation of education, teachers' digital teaching competencies have become a key indicator influencing their overall capabilities and a core driving force for enhancing educational quality during this digital revolution [1, 2]. The digital teaching competencies required of educators in the digital age can be referenced and studied using the modern teacher knowledge structure theory, specifically the TPACK knowledge framework [3].

The full name of the TPACK knowledge framework is Technology-Integrated Pedagogical Content Knowledge, emphasizing the integrated application of technology in education. It was first proposed by American scholars Mishra and Koehler [4]. The TPACK integration model is

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fundamentally rooted in the educational philosophy of blended learning. It combines the strengths of “transmission-reception” and “autonomous-inquiry,” forming a new teaching concept that emphasizes “meaningful transmission combined with teacher-guided autonomous inquiry” [5, 6]. It comprises three core knowledge domains: technological knowledge, pedagogical knowledge, and subject content knowledge. These domains are interwoven, interconnected, integrated, and organically unified, forming four comprehensive competencies within the teacher knowledge structure: PCK (Pedagogical Content Knowledge), TPK (Technology Pedagogical Knowledge), TCK (Technological Content Knowledge), and TPACK (Technological Pedagogical Content Knowledge) [7, 8]. The TPACK framework guides university instructors' classroom teaching practices, providing direction for selecting appropriate pedagogical methods and information technology tools to enhance their instructional capabilities in blended learning environments [9].

Research findings demonstrate that teacher competencies within the TPACK framework significantly enhance the teaching capabilities of higher education faculty [10]. Luo et al. analyzed the practical implications of integrating the TPACK framework into online teaching within the same discipline. They noted that the TPACK framework promotes collaborative abilities among journalism instructors during online teaching delivery, and that teachers' personal philosophies in online music classrooms can be predicted based on the TPACK framework [11]. Araújo Filho et al. designed a blended collaborative teaching model to cultivate pre-service teachers' technological, pedagogical, and content knowledge (TPACK). During training, these three knowledge domains intersected, enabling pre-service teachers to construct pedagogical knowledge through collaborative practices [12]. Maor enhanced student learning experiences using digital tools like tablets and electronic portfolios, designing online courses based on the TPACK framework. This approach boosted student confidence and positioned them as prospective digital educators [13]. Yan's research highlighted that the TPACK framework—encompassing teacher knowledge integration and educational technology application—provides pre-service teachers with a technology-oriented instructional model grounded in theory, practice, and project-based learning, thereby enhancing their educational technical expertise [14]. Hafiz et al. cultivated teachers' blended learning skills through face-to-face, synchronous, and asynchronous online learning. The study demonstrated a significant increase in teachers' technological, pedagogical, and content knowledge literacy, offering new approaches to enhancing teacher professional skills [15]. Tan et al. systematically measured English teachers' TPACK in multimodal courses. Teachers demonstrated high acceptance of TPACK tools used in classrooms, with varying degrees of improvement in their ability to integrate content, pedagogy, and technology [16]. Benson et al. developed a TPACK-based teacher professional competence evaluation model, arguing that instructors who effectively combine and present teaching content, technology, and knowledge in specific ways to students cultivate their pedagogical capabilities [17]. Nurdiani et al. revealed the TPACK framework's potential application in biology teachers' reasoning patterns and modes. Through a quasi-experimental design involving 49 biology teachers, the framework facilitated participants' transition from transitional to formal reasoner categories while also enhancing their logical thinking abilities [18]. Brinkley-Etzkorn applied the TPACK framework to evaluate an online teacher training model. Surveys indicated that teachers' pedagogical competence improved post-training, with moderate gains also observed in online teaching effectiveness [19]. Drajadi et al. examined the application of technology, pedagogy, and content knowledge among pre-service teachers and in-service teachers in smart classrooms. The study indicated that pre-service teachers or teachers possessing these three teaching characteristics demonstrated strong potential for enhancing teaching competence [20].

Additionally, scholars have examined the impact of TPACK-based online teaching models on student learning outcomes and instructional effectiveness [21, 22]. Yang observed low student engagement and insufficient practical content in traditional software testing courses, prompting the introduction of a TPACK-based blended teaching model that leveraged multimedia, online learning, and WeChat. Test results demonstrated improvements in students' learning abilities, knowledge expansion capabilities, and learning interest [23]. Wang et al. employed a randomized controlled trial to investigate the effects of a TPACK-based blended online-offline teaching model on theoretical knowledge and comprehensive abilities among graduate students in gynecologic oncology. Students in the TPACK intervention group demonstrated significantly enhanced case analysis skills and clinical competence post-intervention, outperforming those in the traditional teaching group [24]. GAO et al. applied the TPACK teaching model in biology classrooms using a methodology similar to Wang et al.'s. The experimental group achieved significantly higher individual scores than the control group, with over 85% of students reporting that the model enhanced their self-directed learning and problem-solving abilities [25]. Liao validated the applicability of a TPACK-based blended teaching model for tourism English. The study demonstrated that this model overcomes the temporal and spatial constraints of traditional teaching, enhances teacher-student interaction, fosters an autonomous and personalized learning environment, and improves the quality of tourism English instruction [26]. Susilawati et al. compared TPACK-based and traditional teaching models in social studies learning outcomes. They found students in the TPACK model demonstrated proactive, creative engagement and independent thinking skills, enabling them to rapidly master teacher-delivered knowledge [27]. Enhancing vocational education teachers' digital teaching competencies is a critical task in educational modernization. The aforementioned research provides insights and direction for vocational educators to improve their digital teaching capabilities, enabling them to better adapt to the educational demands of the digital age and thereby advance the development of digital teaching in education [28, 29].

This paper constructs a TPACK-based teaching competency enhancement framework centered on seven elements: TK, PK, CK, PCK, TCK, TPK, and TPACK. Subsequently, it introduces digital environments and identifies four pathways for enhancing teachers' blended instructional design capabilities in such settings. A questionnaire survey was conducted with randomly selected teachers from different provinces. The survey primarily maps the overall level of teachers' development in information-based teaching competencies by examining the mean scores of TPACK's three core elements and four composite elements. A linear regression model is employed to further investigate the relationships among the seven TPACK components. To reflect the impact of various factors on TPACK, a one-way analysis of variance (ANOVA) was conducted on teachers' scores across TPACK factors and overall scores under different influencing conditions. This analysis identified significant pairwise differences in post-hoc comparisons for each factor.

2 A TPACK Framework-Based Model for Enhancing Teaching Competencies

2.1 Teaching Competence

Ability refers to the individual psychological characteristics necessary for successfully completing certain activities. That is, ability is the psychological trait that directly influences activity efficiency and enables activities to proceed smoothly. It can also denote the talent and strength required to perform a specific activity competently. Based on research findings, the

importance of teaching ability in the field of education can be summarized [30]. The Encyclopedia of Education defines teaching ability as the specific behavioral characteristics and comprehensive capabilities demonstrated by teachers during instructional activities, which are intrinsically linked to teaching objectives.

2.1.1 Technical Knowledge (TK)

With the continuous advancement of technology, people's understanding of technical knowledge is also evolving. Specific technologies and related theoretical knowledge vary across different fields or industries. In this context, technical knowledge refers to educators' comprehension and operational proficiency with various technological tools. When applying technical knowledge, teachers should integrate information technology into teaching practices according to subject characteristics, providing students with richer, more personalized, and interactive learning experiences. This approach helps students better grasp skills, enhance tactical awareness, and advance their development within the field.

2.1.2 Pedagogical Knowledge (PK)

Pedagogical Knowledge (PK) refers to the professional expertise teachers possess regarding how to effectively organize and impart knowledge. It encompasses a broad range of content, including but not limited to instructional design, planning teaching activities, organizing and managing instruction, and conducting assessment and providing feedback. It incorporates not only teaching theories and principles but also integrates practical experience and professional judgment to meet the diverse learning needs and unique characteristics of different students.

2.1.3 Content Knowledge (CK)

Subject-specific content knowledge refers to the knowledge and understanding possessed within a particular academic discipline. It constitutes an essential knowledge domain for teachers in the teaching process, serving as the foundation for their deep comprehension and effective transmission of core concepts, principles, theories, and techniques within the subject. Teachers must grasp the core concepts of the subject they teach, master sufficient subject-specific expertise, and integrate subject content knowledge with classroom instruction seamlessly. During lessons, teachers should break down essential skills into easily understandable and masterable steps. By accurately conveying and demonstrating correct techniques, teachers can help students learn and improve skills effectively.

2.1.4 Pedagogical Content Knowledge (PCK)

Subject pedagogy knowledge refers to a teacher's deep understanding of subject content within a specific discipline, along with the knowledge of teaching methods and strategies for effectively conveying that content to students. Subject pedagogy knowledge represents the knowledge and ability of teachers to organically integrate subject content knowledge with teaching methods and strategies, aiming to support student learning and development. By synthesizing these elements of subject pedagogy through their understanding of professional knowledge, teachers present instructional content in ways that are accessible to students. This enables teachers to deliver targeted, meaningful, and effective instruction, helping students build deep subject understanding and practical skills.

2.1.5 Integrating Technological Content Knowledge (TCK)

Discipline-specific content knowledge in technology integration refers to a teacher's ability to integrate technology within a specific subject area—that is, how educators effectively combine

technological tools and resources with subject matter during instruction to support student learning and development. TCK emphasizes that teachers must possess a deep understanding of subject matter when using technology, along with the knowledge and skills to apply technology within subject instruction. This integrated knowledge and skill set enables teachers to create meaningful, relevant, and effective learning experiences for students. Examples include providing students with relevant videos, literature, and interactive exercises through online teaching platforms, or using interactive whiteboards or virtual reality technology to create rich learning environments that deepen students' understanding and application of subject content.

2.1.6 Teaching Methodology Knowledge (TPK) for Integrated Technologies

The pedagogical knowledge of integrating technology refers to how teachers effectively utilize technological tools and resources to support student learning and development during instruction. TPK emphasizes educators' ability to integrate technology with effective teaching methods and strategies in their practice. Specifically, it involves teachers' capacity to apply various information technologies in classroom teaching to enhance or supplement instructional approaches and improve teaching quality.

2.1.7 Integrating Technological Pedagogical Content Knowledge (TPACK)

TPACK (Technology-Integrated Pedagogical Content Knowledge) refers to the integration of technological knowledge, pedagogical knowledge, and subject content knowledge [31]. It serves as a framework within the field of education to guide teachers on how to effectively integrate technological tools and teaching methods to support student learning. Teachers' approaches to applying or organizing the integration of technology, pedagogy, and subject content knowledge in instruction may vary based on individual background, educational philosophy, and teaching experience. There is no universally accepted solution. The optimal approach involves teachers flexibly applying the interplay between technological knowledge, pedagogical knowledge, and subject content knowledge based on student characteristics and needs, while mastering the ability to integrate these three elements within specific classroom contexts.

Representatives of the “integration-promoting” perspective, Koehler and Mishra, propose that TPACK constitutes an organic whole generated from three foundational knowledge domains: Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK). These three foundational knowledge areas are interconnected, forming four composite knowledge domains: Pedagogical Content Knowledge (PCK), Technology Pedagogical Knowledge (TPK), Technology Content Knowledge (TCK), and Technology Pedagogical Content Knowledge (TPACK). Among these, TPACK represents the most central composite knowledge. The TPACK framework is illustrated in Figure 1. This framework emphasizes the importance of TK, PK, and CK in teaching, viewing TPACK as the result of interactions among TK, PK, CK, TPK, TCK, and PCK. These components are placed within a circle representing the context, though context factors were not included when the TPACK framework was first proposed. It is closely tied to specific situations and functions through concrete practice. As research deepened, scholars increasingly recognized that teachers' use of technology in instruction is also influenced by multiple factors such as environment and psychology. This signifies that TPACK is a new knowledge system involving numerous contexts and factors that are interwoven within it.

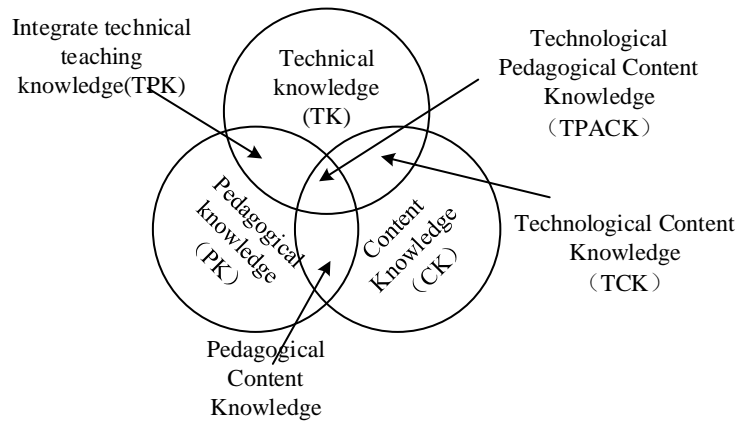


Figure 1: TPACK framework

2.2 Enhancing Blended Teaching Competencies Based on the TPACK Framework

To enhance teachers' blended teaching competencies, this study constructs a framework for cultivating teachers' online-offline blended teaching design capabilities based on the TPACK framework. It also summarizes pathways for improving teachers' blended teaching design competencies in digital environments. Figure 2 presents the framework for cultivating teachers' online-offline blended teaching design capabilities based on the TPACK framework.

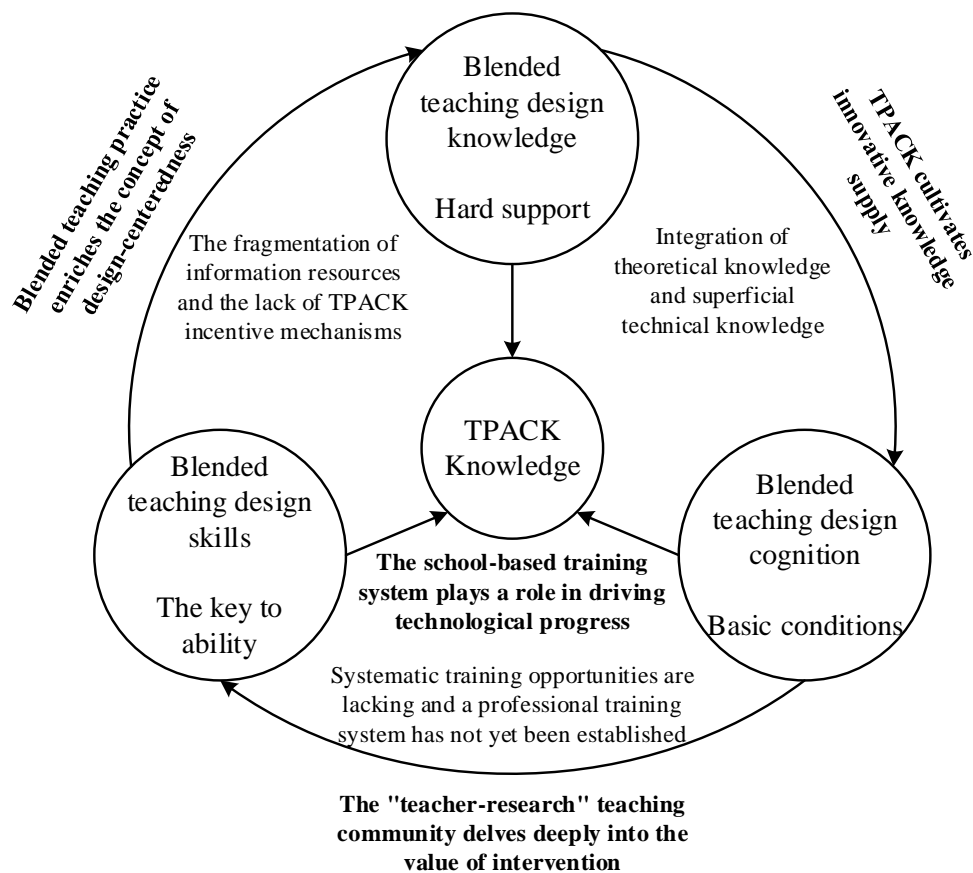


Figure 2: The teachers' design ability culture based on TPACK framework is developed

2.2.1 TPACK Cultivation: Innovative Knowledge Provision

First, consolidate the foundational knowledge logic of various knowledge domains within TPACK and their interwoven, derivative integrated knowledge. Based on the essence of smart classroom teaching, refine the TPACK structural framework by updating outdated knowledge and exploring a new TPACK knowledge framework for educators in the era of smart education.

Second, engage in specialized, conceptual theoretical study to deepen the potential value of academic research within teaching. This enriches one's blended learning knowledge framework, transforming scientific academic theories into contextualized knowledge that guides teaching practice. This achieves the conversion and deepening of theory into practice.

2.2.2 Blended Learning Practices: Deepening the Design-Centered Approach

The practice of blended teaching requires educators to systematically study the steps, processes, and elements of traditional instructional design while also undergoing hands-on training in digital technology applications and the use of information-based teaching tools [32]. Engaging in the process of blended teaching design offers educators and novice teachers optimal learning opportunities to explore integrated online-offline teaching models. By identifying steps for blended teaching design tasks of varying complexity, they leverage logical cognition within existing knowledge structures to create multidimensional, bidirectional blended teaching designs that integrate online and offline elements, ultimately aimed at solving practical teaching challenges.

2.2.3 Teacher-Researcher Teaching Community: Deepening the Value of Intervention

The practical nature of the TPACK framework necessitates that teachers enhance their blended teaching design capabilities through extensive instructional practice. This involves developing competencies aligned with subject knowledge, pedagogical knowledge, and technological knowledge, as well as the integrated competencies generated by their interaction. Establishing “teacher-research” communities such as seminar salons and blended teaching workshops provides educators with support for implementing blended teaching practices using information technology. This fosters the dissemination of blended teaching experiences, facilitates the sharing of online and offline teaching resources, and advances the upgrading of blended teaching design and practical skills. Consequently, it cultivates a positive atmosphere of mutual exchange, collaborative learning, and mutual improvement.

2.2.4 School-Based Training System: Empowering Teachers Through Technological Momentum

Teachers' hybrid teaching design and implementation capabilities within information-based instructional environments cannot be achieved overnight. They require extensive theoretical study and practical exploration. Only through sustained internalization of theory and externalization of practice can teachers ensure continuous improvement in their hybrid teaching skills and their ability to design and implement hybrid instruction. First, fully leverage campus platforms to conduct TPACK theoretical research. Through exploring the theoretical dimensions of the TPACK framework—Technological Knowledge (TK), Pedagogical Knowledge (PK), and its related dimensions (TPK, TCK, PCK)—teachers continuously enrich their TPACK knowledge. Second, deeply explore the practical teaching value of internship schools. Higher education institutions and partner schools should fully explore new training models that leverage technology to empower teacher professional development. Emerging technologies such as interactive online systems, artificial intelligence, and cloud computing should be utilized to drive innovation and transformation in blended teaching approaches.

Finally, establish a school-based blended training platform integrating online and offline components. This platform should facilitate collaborative exploration of blended teaching design among teachers, experts, and researchers, fostering the mutual development of individual educators and the school community.

3 Research on Teachers' Instructional Competence Based on TPACK

3.1 Study Design

3.1.1 Research Tools

This study primarily employed a questionnaire survey method to investigate the current state of teachers' information-based teaching capabilities. The collected data were organized and statistically analyzed using SPSS statistical software, supplemented by interview surveys. The gathered interview materials were systematically organized and summarized.

3.1.2 Research Subjects

To investigate the current state of teachers' information-based teaching proficiency, this study employed random sampling to select 363 teachers as research subjects—198 from Province H and 165 from Province G—and conducted a questionnaire survey. Additionally, 15 teachers from these schools were selected for one-on-one structured interviews. Among the interview samples, six were male teachers and nine were female teachers, with female teachers constituting the majority in terms of numbers. Age distribution showed that 60% of the sample was aged 36-45, constituting the largest group. Regarding teaching experience, 50% had over 20 years of experience, representing the majority. In terms of educational background, 70% held master's degrees, forming the predominant group. Each interview was limited to 40 minutes to ensure the accuracy of the results.

3.2 Research Findings and Analysis

3.2.1 Descriptive Statistical Analysis

In descriptive statistical analysis, this study focuses on examining the overall level of teachers' development in information-based teaching competencies by investigating the mean values of TPACK's three core components and four composite components.

Higher mean values (M) indicate a higher level of proficiency in a given area. Figure 3 presents the descriptive statistical analysis of teachers' TPACK components, with an overall mean of 3.3065 (SD=0.5486) across the seven TPACK elements. The research scale employed a 5-point rating system comprising 34 items, yielding scores ranging from 34 to 170, with a theoretical mean of 3.000. It can be observed that the mean values for all TPACK components are close to the theoretical median of 3.000. This data indicates that teachers' overall TPACK proficiency is at a moderately high level. Examining individual components reveals that the mean for Content Knowledge (CK) is 3.5927, the highest among all components. The mean for Pedagogical Content Knowledge (PCK) is 3.4279, following closely behind. The average score for Technological Knowledge (TK) was 2.9245, the lowest among all components. This indicates that teachers possess strong subject knowledge and pedagogical expertise, demonstrating solid mastery of subject content and teaching methodologies. However, their proficiency in technological knowledge remains relatively low.

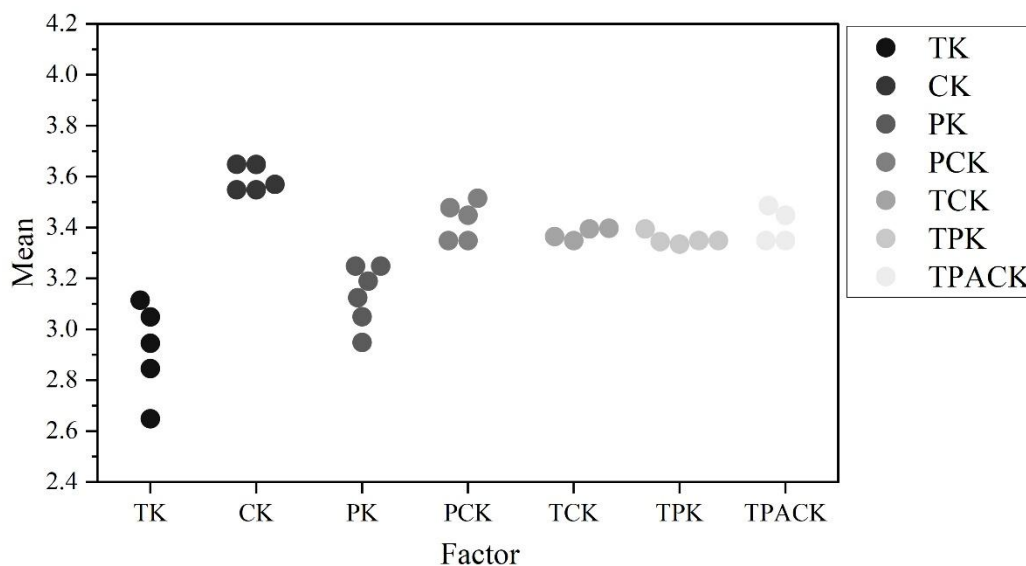
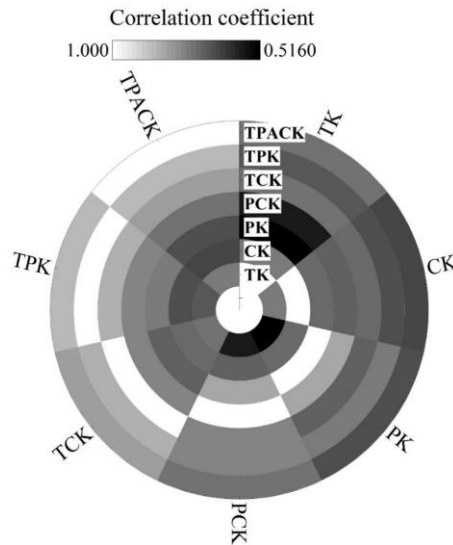


Figure 3: The teacher TPACK elements describe statistical analysis

3.2.2 Correlation Analysis

To determine whether the development of TPACK components is interrelated, a correlation analysis of the seven elements within the TPACK framework is required. Figure 4 illustrates the correlations among the TPACK components for teachers. The seven elements within the TPACK framework exhibit significant positive correlations. Among these, the correlation coefficient between Technology-Integrated Pedagogical Content Knowledge (TPACK) and Technological Pedagogical Knowledge (TPK) is the highest ($r=0.8648$, $p<0.01$). This indicates that when teachers develop their information-based teaching competencies, the level of their TPACK is strongly associated with their mastery of technological pedagogical knowledge. Additionally, the two lowest correlation coefficients were observed between pedagogical knowledge (PK) and technological knowledge (TK) ($r=0.5163$, $p<0.01$), though they still exhibited a relatively strong positive correlation. This indicates that within the TPACK framework, enhancing any single element positively influences the others, suggesting that the development of TPACK components is inherently mutually reinforcing. Within technological knowledge (TK), the highest correlation coefficient was observed between TK and TPACK ($r=0.7548$, $p<0.01$), followed by TK and CK ($r=0.7452$, $p<0.01$). This implies that when developing information-based teaching competencies, educators must not only acquire sufficient technological and subject-specific knowledge but also achieve effective integration of all elements within information-based teaching to enhance instructional effectiveness and quality. Within the domain of Technology-Content Knowledge (TCK), both TPACK and TCK exhibit highly significant positive correlations (TPACK-TCK: $r=0.8452$, $p<0.01$; TPACK-TCK: $r=0.8069$, $p<0.01$). This further demonstrates that strengthening subject-specific technological knowledge drives comprehensive improvement in teachers' digital teaching competencies.



Note: all the elements in the diagram are **p<0.01.

Figure 4: The correlation between the elements of the teacher TPACK

3.2.3 Regression Analysis Among Dimensions of Teachers' TPACK

To further investigate the relationship between teachers' CK, PK, TK, PCK, TPK, and TCK knowledge and their TPACK proficiency, this study sets TPACK as the dependent variable and employs six independent variables: TK, CK, PK, PCK, TPK, and TCK. Regression analysis was conducted, with specific results presented in Table 1. $R^2 = 0.7489 > 0.6$ indicates that the linear regression model exhibits excellent fit. This means the computational results reliably reflect that TK, CK, PK, PCK, TPK, and TCK collectively explain 74.89% of the variation in TPACK. The model equation is:

$TPACK = 0.0785 + 0.1485*TK + 0.0455*CK + 0.1265*PK + 0.0969*PCK + 0.0948*TCK + 0.5455*TPK$. The regression equation is significant ($F=73.945, P<0.001$), indicating that at least one of these six variables significantly influences the dependent variable TPACK. Among them, the significance P-values for TK, CK, PCK, PK, and TCK are all greater than 0.05, meaning these factors do not have a significant impact on TPACK. The regression coefficient for TPK is 0.5495 ($t=7.5486, P=0.00<0.01$), indicating that TPK exerts a significant positive influence on TPACK. The results demonstrate that integrating pedagogical knowledge of technology into teacher training significantly enhances overall TPACK proficiency.

Table 1: Regression analysis of each element

Model	Unnormalized coefficient		Normalization factor	T	Sig.	VIF
	B	Standard error	Beta			
Constants	0.0785	0.1858	-	0.3485	0.7452	-
TK	0.1485	0.0798	0.1458	1.9488	0.0548	3.1248
CK	0.0455	0.1048	0.0348	0.3456	0.7952	4.9485
PK	0.1265	0.1154	0.1248	1.2458	0.2485	5.3485
PCK	0.0969	0.1096	0.0896	0.9485	0.3574	4.9485
TCK	0.0948	0.0978	0.0948	1.0486	0.3486	4.5485
TPK	0.5455	0.0785	0.5495	7.5486	0.0000	2.6485
$R^2=0.7489$						
$F=73.945, P<0.001$						
Dependent variable: TPACK						

3.3 Analysis of Constituent Element Outcomes

3.3.1 TK

The TK elements comprise five survey items coded as TK1 to TK5. The mean and standard deviation of TK element scores are shown in Figure 5. Teachers scored higher on TK1 (familiarity with computer operations) and TK5 (interest in cutting-edge educational technology), with scores of 3.1145 and 3.0487 respectively, exceeding the mean of 3. The survey results indicate that most teachers have mastered common information technologies and demonstrate strong interest in integrating IT with their courses. However, scores for TK2 (using online platforms to solve problems), TK3 (independently resolving IT usage issues), and TK4 (applying multimedia 3D animation) were relatively low, suggesting teachers are less adept at utilizing media technologies such as video editing.

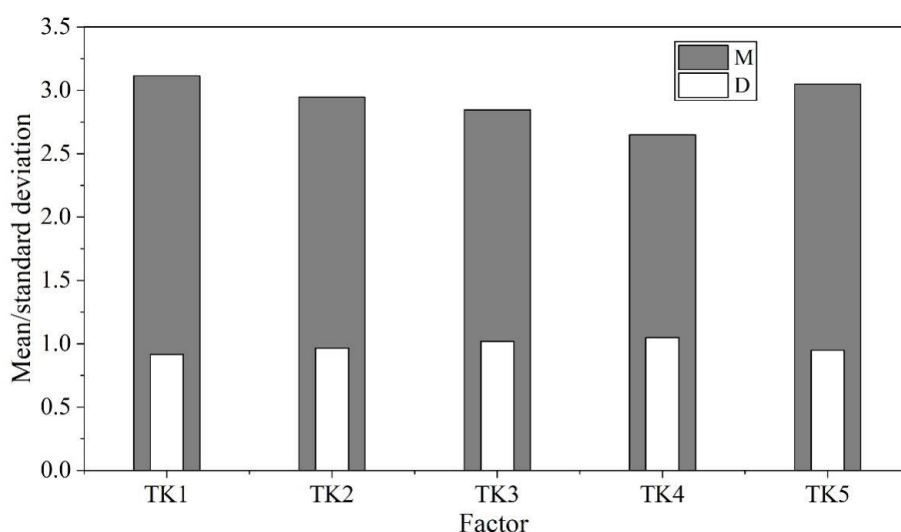


Figure 5: The TK factor scores average

3.3.2 PK

Figure 6 shows the scores for pedagogical key factors, with overall higher scores for teaching methodology elements. The results indicate that most teachers can observe student differences in performance (PK1) in the classroom and are adept at adjusting teaching pace (PK2), modifying teaching styles (PK3), switching teaching methods (PK4), identify learning difficulties and misconceptions (PK5), and manage classroom organization (PK6). The respective scores for these six elements are 3.2485, 2.9485, 3.0498, 3.1248, 3.2485, and 3.1894.

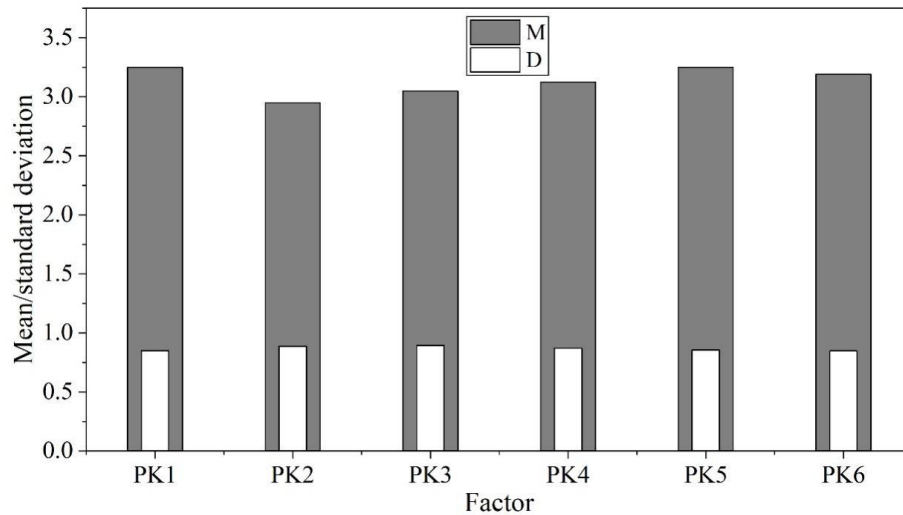


Figure 6: PK factor score

3.3.3 CK

Figure 7 presents the findings and analysis of the CK component survey. The results indicate that teachers possess relatively comprehensive subject textbook knowledge (CK1), demonstrate strong interest in cutting-edge scientific knowledge (CK3), the history of their discipline (CK4), and real-world knowledge, while also achieving commendable outcomes in instructional design (CK2). The scores for CK1 to CK5 are 3.6485, 3.6482, 3.5485, 3.5698, and 3.5485, respectively.

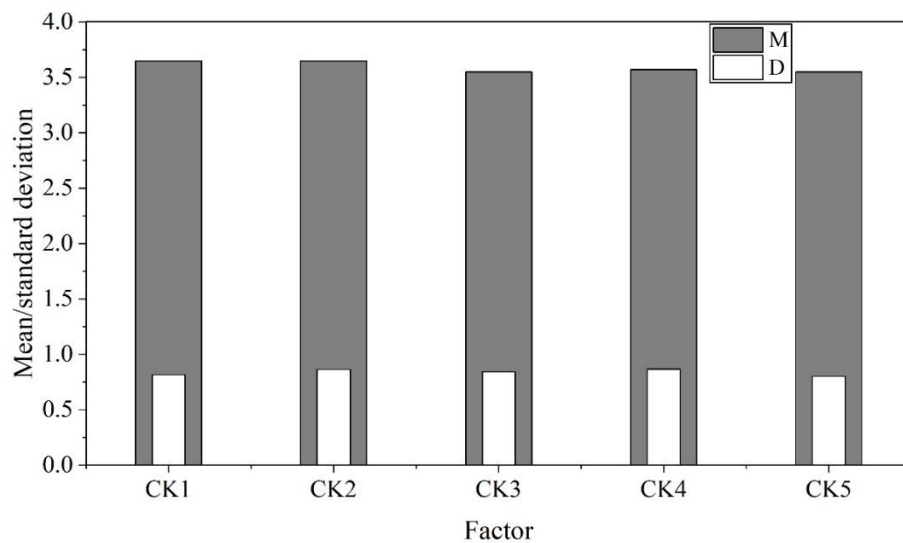


Figure 7: The findings and analysis of CK elements

3.3.4 PCK

Using PCK1-PCK5 as coding elements for PCK, the results are shown in Figure 8. Teachers scored above 3.0 on all survey items, indicating that teachers excel at selecting effective teaching strategies for knowledge explanation (PCK1), establishing knowledge connections between chapters (PCK3), and developing lesson plans (PCK4). PCK2 (selecting different teaching methods for different instructional themes) achieved the highest score with the lowest standard deviation ($M=3.5152$, $SD=0.7896$), indicating that teachers generally possess the flexibility to apply pedagogical knowledge and switch teaching methods according to different

knowledge types and instructional contexts. PCK5 (selecting different representations for different types of knowledge) scored the lowest with the highest standard deviation ($M=3.3488$, $SD=0.8199$), suggesting that teachers are less proficient in this area.

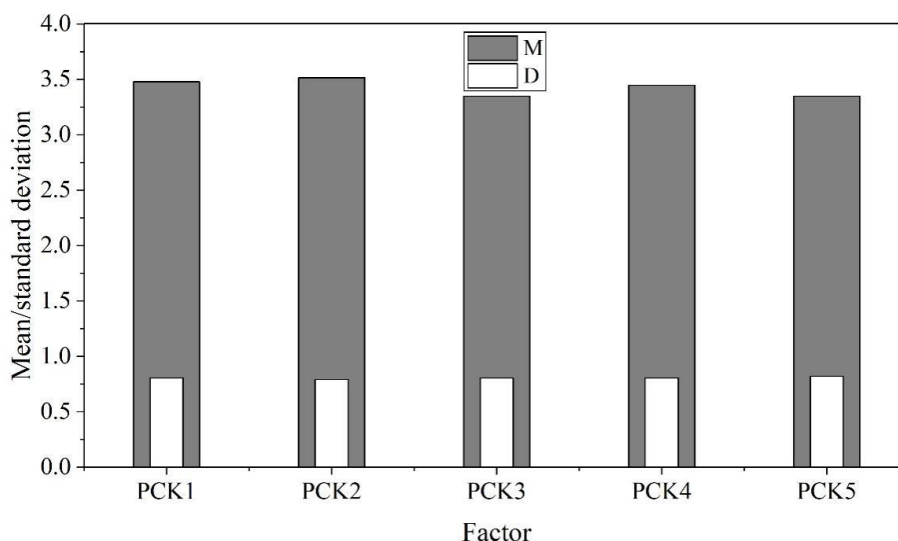


Figure 8: PCK score

3.3.5 TCK

TCK encompasses four items as shown in Figure 9. Among these, TCK1 (Using Handheld Technology for Inquiry-Based Learning) and TCK2 (Employing Educational Technology for Collaborative Learning) scored relatively low, while TCK3 (Preparing Educational Technology-Integrated Lesson Plans) and TCK4 (Focusing on Cutting-Edge Educational Technology) scored higher at 3.3485, 3.3948, 3.39689, and 3.3648, respectively. This indicates that teachers excel in selecting and designing educational technology but demonstrate weaker abilities in integrating technology with subject knowledge during implementation. Their capacity to conduct chemistry research projects through collaborative group work also remains relatively underdeveloped.

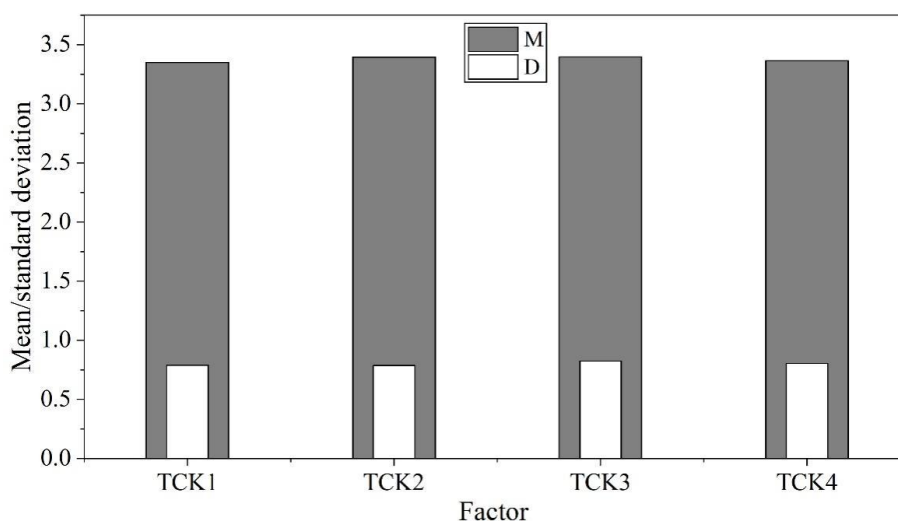


Figure 9: TCK factor score

3.3.6 TPK

Figure 10 shows the scores for TPK elements. Among them, TPK2 (using mobile apps to support teaching), TPK3 (selecting educational technology beneficial to teaching careers), TPK4 (preferring information technology for home-school collaboration), and TPK5 (focusing on cutting-edge educational technology) scored relatively high. However, TPK1 (selecting appropriate educational technology based on student circumstances) scored relatively low (3.3485). This indicates that teachers have generally mastered the knowledge required to integrate technology into teaching, but their ability to select technology based on teaching methods remains inadequate. There is also room for improvement in understanding the internal connections between these two types of knowledge, suggesting that teachers' overall level of technology integration in teaching still needs enhancement.

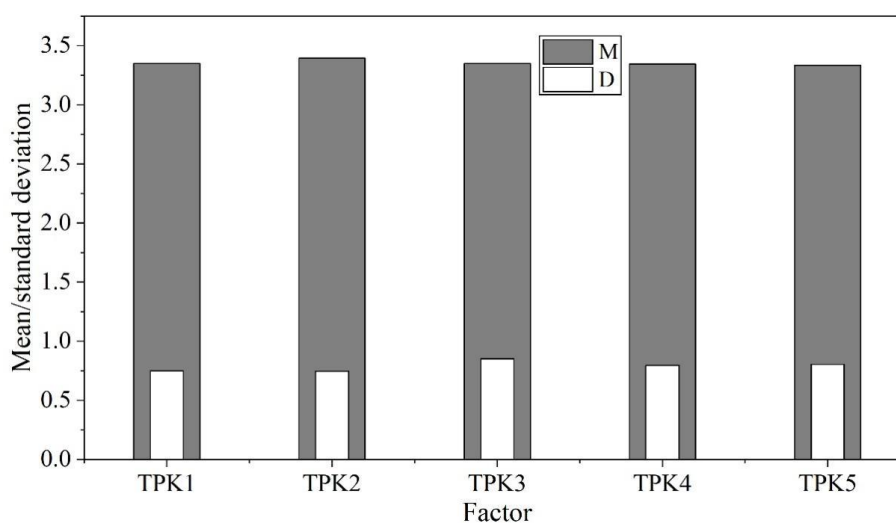


Figure 10: TPK factor score

3.3.7 TPACK

Figure 11 presents the survey results and analysis of TPACK components, coded as TPACK1-TPACK3. All scores averaged above 3 points, indicating a moderately high level of proficiency. TPACK1 (Appropriate integration of subject knowledge, technology, and pedagogical knowledge in classroom teaching), TPACK3 (Adaptation of technology, pedagogy, and subject knowledge based on learner needs), and TPACK4 (Effective management of the relationship between subject knowledge, information technology, and pedagogy) scored relatively higher at 3.4858, 3.4485, and 3.3486, respectively. This indicates that through systematic training, teachers can effectively integrate subject knowledge, pedagogical knowledge, and technological knowledge into teaching. TPACK2 (demonstrating leadership in collaborative integration of subject, pedagogy, and technology) scored relatively low, suggesting teachers exhibit uncertainty when determining the suitability of technology and pedagogy for chemistry instruction. The “relevance” between various types of knowledge requires deeper clarification, and teachers' ability to effectively integrate knowledge can be further enhanced.

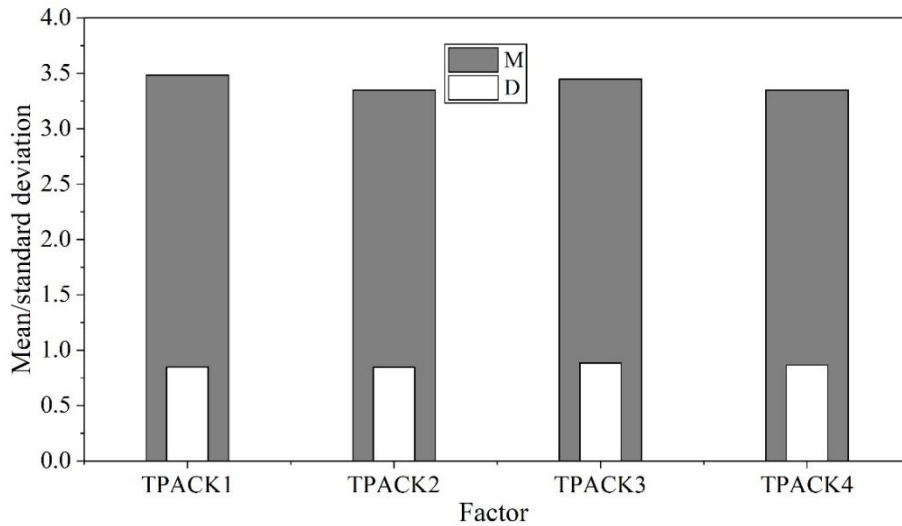


Figure 11: Survey results and analysis of TPACK elements

3.4 Analysis of Variability in TPACK Influencing Factors

3.4.1 Educational Attainment Differences

A one-way ANOVA was conducted on the TPACK factors and overall scores for teachers with different educational backgrounds, with results shown in Figure 12.

Significant differences ($P < 0.05$) were found between teachers with different educational backgrounds in the dimensions of Pedagogical Knowledge of Science (PK), Content Knowledge of Science (CK), Technological Pedagogical Knowledge of Science (TPK), Technological Content Knowledge (TCK), Technological Pedagogical Content Knowledge (TPACK), and the overall dimension. No significant differences were observed in the other dimensions. Post-hoc multiple comparisons were conducted on data showing significant differences, listing pairwise comparisons with significant differences for each factor.

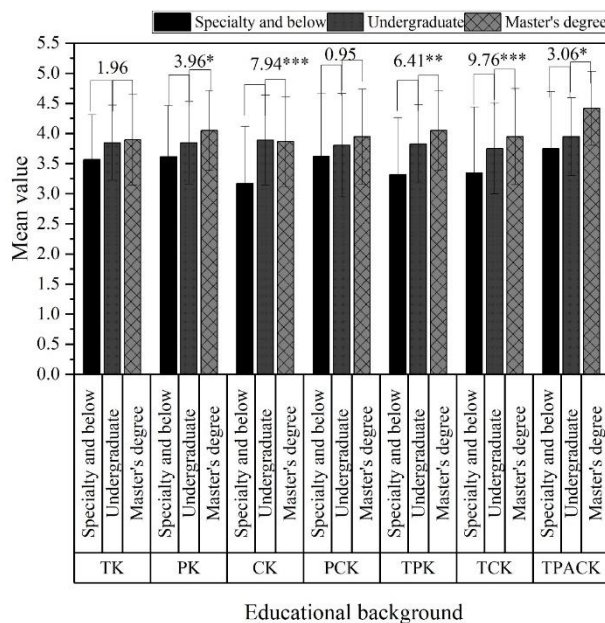


Figure 12: The variance analysis of different degree of degree of TPACK factors

3.4.2 Internship Variations

This study examines differences in TPACK based on teaching practicum participation, focusing on whether participants engaged in off-campus student teaching, online practicum, or in-person practicum.

Figure 13 presents the analysis of practicum variations. Participation in teaching practicum significantly impacts TPACK ($t=2.3488$, $p=0.008$). Teachers who completed teaching practicum demonstrated a significantly higher mean TPACK score (3.5419 ± 0.6444) compared to those without such experience (3.3214 ± 0.4513). This indicates that teaching practicum participation significantly enhances teachers' overall TPACK proficiency.

Similar patterns emerged for the three additional practicum conditions: whether the practicum involved students outside the school, whether it was conducted online, or whether it was conducted offline. Teachers who participated in these types of practicums also demonstrated higher average TPACK scores than those who did not. The mean TPACK scores for teachers who participated in off-campus practicum, online practicum, and offline practicum were 3.621, 3.6084, and 3.5856, respectively.

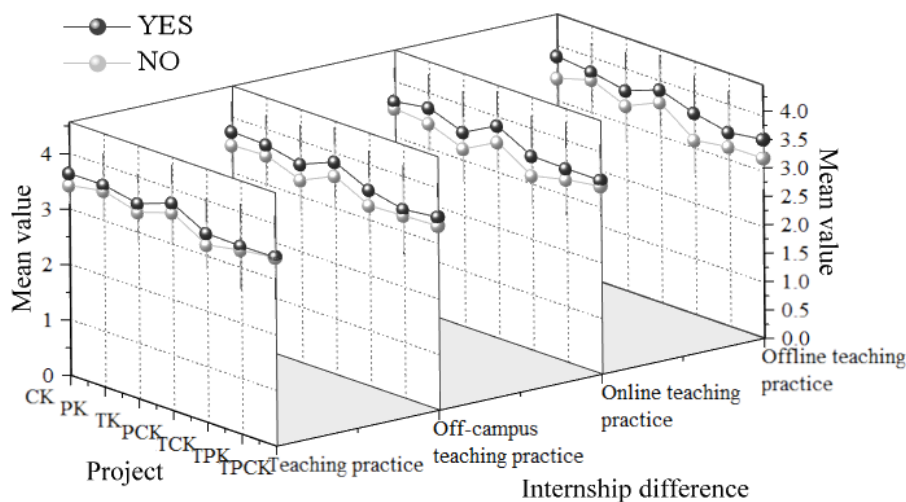


Figure 13: Analysis of interpractice differences

4 Conclusion

This study outlines pathways for enhancing teachers' blended teaching competencies within the TPACK framework. Employing random sampling surveys, it collects data on teachers' information-based instructional proficiency. Using the seven dimensions of TPACK as entry points, it conducts a TPACK-based investigation into teachers' instructional capabilities. The average score for the seven TPACK elements is 3.3065, with a standard deviation of 0.5486. With all component values approaching the theoretical mean of 3, indicating teachers' overall TPACK proficiency is at an upper-middle level. To determine inter-component correlations, a correlation analysis was conducted among the seven TPACK elements. The highest correlation was found between TPACK and TPK ($r=0.8648$, $p<0.01$), indicating a strong association between overall teaching competence and technological teaching competence. With TPACK as the dependent variable, a regression analysis of associated factors yielded $R^2 = 0.7489 > 0.6$. This indicates excellent model fit for the linear regression, explaining 74.89% of the variation in TPACK. The regression coefficient for TPK was 0.5495 ($P < 0.01$), confirming that TPK significantly enhances the overall level of TPACK.

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