INTERNATIONAL JOURNAL OF RESEARCH AND INNOVATION IN SOCIAL SCIENCE (IJRISS)
ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue III March 2026

Development and Validation of a Blended Teaching Design and Teaching Strategy Scale for Technology Education

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DOI: https://doi.org/10.47772/IJRISS.2026.100300224

Received: 12 March 2026; Accepted: 19 March 2026; Published: 01 April 2026

ABSTRACT

Blended teaching has become an important instructional approach in higher education, particularly in technology-related programs where students need to develop both theoretical understanding and practical skills. However, there is a lack of specialized instruments for assessing teachers' competencies in designing and implementing blended teaching in the technology education context. This study aimed to develop and validate a Blended Teaching Design and Strategy Scale based on an integrated theoretical framework combining the Practical Inquiry Model (PIM) and Technological Pedagogical and Content Knowledge with Collaborative Learning (TPACK-CL). An explanatory sequential mixed-methods design was employed. First, qualitative interviews were conducted with 10 technology program teachers to inform item generation. Then, a quantitative survey involving 224 teachers from three polytechnics in Guangdong Province, China was conducted to test the instrument's psychometric properties. Item analysis, exploratory factor analysis, and confirmatory factor analysis were used to examine the scale's reliability and validity. The final scale consists of 48 items across two subscales: the teaching design subscale includes four dimensions (triggering event, exploration, integration, resolution) with 20 items, and the teaching strategy subscale includes eight dimensions (technological knowledge, content knowledge, pedagogical knowledge, pedagogical content knowledge, technological content knowledge, technological pedagogical knowledge, technological pedagogical and content knowledge, and collaborative learning) with 28 items. Reliability analysis showed strong internal consistency with Cronbach's alpha of 0.899 for the design subscale and 0.889 for the strategy subscale. Validity analysis confirmed good construct validity, convergent validity, and discriminant validity. The findings demonstrate that the developed scale is a reliable and theoretically grounded instrument for assessing blended teaching practices in technology education. This instrument can support teacher professional development, inform institutional training initiatives, and contribute to research on effective blended teaching implementation.

Keywords: Blended teaching, scale development and validation, blended teaching design, blended teaching strategies, technology education

INTRODUCTION

The rapid advancement of digital technologies has transformed teaching and learning practices into higher education, leading to the widespread adoption of blended teaching models that integrate online and face-to-face learning environments[1]. Blended teaching offers significant advantages, including flexible learning pathways, improved interaction, and enhanced opportunities for collaborative and inquiry-based learning[2]. These advantages are particularly important in technology-related programs, where students must develop both conceptual understanding and practical problem-solving skills[3]. However, the effectiveness of blended teaching depends not only on the use of digital technologies but also on the quality of teaching design and the strategic integration of pedagogy, content, and technology[4]. Existing studies have proposed various blended learning models, yet there remains a lack of standardized instruments capable of systematically measuring teachers' competencies in designing and implementing blended teaching practices in technology education contexts. To address this gap, the present study develops and validates a Blended Teaching Design and Strategy Scale based on an integrated framework combining the Practical Inquiry Model (PIM) and the TPACK-CL framework, providing a comprehensive tool for evaluating and improving blended teaching practices in technology programs.

Research Background

Entering the 21st century, science and technology have reshaped human society with unprecedented depth and breadth, and the field of education is no exception[5]. Among these developments, blended teaching, as an innovative model that combines the advantages of online digital learning and face-to-face classroom instruction, has become a key trend in higher education reform and research globally[6][7]. By offering flexibility, personalized learning pathways, and enhanced connections between teachers and students as well as among peers, it holds significant potential for improving teaching effectiveness and learning experiences[8][9]. In Technology Programs (such as Computer Science, Engineering, Intelligent Manufacturing, etc.) that emphasize practical skills and rapid technological iteration, blended teaching is regarded not only as an effective means of imparting complex professional knowledge but also as a crucial pathway for cultivating students' critical thinking, innovative abilities, and lifelong learning habits[10].

However, the success of blended teaching extends far beyond simply moving content online. Its effectiveness fundamentally depends on systematic, carefully planned teaching design and flexible, appropriate teaching strategies[11][12]. teaching design outlines the scientific phases and processes for learning experiences, while teaching strategies involve the specific methods teachers use to integrate technology, pedagogy, and content to promote deep learning[13]. Unfortunately, current blended teaching practices in the technology field often face challenges: many teachers have only a superficial understanding of blended instruction, lacking guidance from systematic design frameworks, leading to fragmented online and offline components, or an excessive focus on technological tools themselves while neglecting the deep integration of pedagogy and content[14][15]. Such inadequacies in design and strategy are widely recognized as key reasons for insufficient student engagement and declining learning motivation[16].

Problem Statement

To optimize practice and enhance the quality of blended teaching, it is first necessary to scientifically and accurately assess teachers' implementation levels in these two core dimensions. Although existing research has proposed various blended teaching models and strategic frameworks, and there are some general instruments for measuring teaching competency or technology acceptance, a significant research gap remains: there is currently a lack of a standardized scale rooted in a solid, integrated theoretical foundation, specifically designed for the characteristics of the technology education context, to systematically evaluate teachers' blended teaching design and strategies.

Existing research either focuses on a single theoretical perspective, failing to capture the multi-faceted, dynamic, and integrated nature of "design" and "strategy" in blended teaching, or develops measurement tools that are highly general but lack specificity, not fully reflecting the unique requirements of technology education for practical inquiry, technology integration, and collaborative problem-solving[17][18]. Therefore, developing a specialized scale with sound psychometric properties holds urgent practical significance for diagnosing the current state of teaching and guiding teacher professional development.

Research Purpose and Significance

To address the aforementioned gap, this study aims to develop and validate a Blended Teaching Design and Strategy Scale based on an integrated framework combining the Practical Inquiry Model (PIM) and Technological Pedagogical and Content Knowledge – Collaborative Learning (TPACK-CL). The PIM[19] provides a four-phase, inquiry-centered design process for blended teaching. The extended TPACK-CL framework integrates the knowledge base required for teachers to effectively implement blended teaching with key collaborative learning strategies. Integrating these two frameworks allows for a comprehensive and multi-dimensional depiction of the complete competency spectrum for technology field teachers in blended teaching, ranging from macro-level process design to micro-level strategy application.

Specifically, following rigorous scale development and validation procedures, this study will sequentially address the following core research questions:

RQ1: How can an initial item pool for the scale be generated based on the integrated PIM and TPACK-CL framework, combined with the practical experiences of technology field teachers?

RQ2: How can the initial items be purified and optimized through reliability and validity testing?

RQ3: What key factors constitute the effective blended teaching designs and teaching strategies implemented by teachers?

LITERATURE REVIEW

This chapter aims to lay the theoretical foundation for the scale development in this study and clarify the research positioning. First, it clarifies the operational definitions of the two core constructs—"teaching design" and "teaching strategies"; within blended teaching. Subsequently, it elaborates on the Practical Inquiry Model, serving as the design framework, and the integrated TPACK-CL framework, serving as the strategy basis, which are the theoretical cornerstones of this research. Finally, by reviewing the limitations of existing relevant measurement tools, it reveals the innovation and necessity of this study.

Blended Teaching Design and Teaching Strategies

Blended teaching is not a simple superposition of online learning and face-to-face instruction; its effectiveness stems from the systematic planning and dynamic execution of two core components: teaching design and teaching strategies. In this study, these two components have clear operational definitions. “Teaching Design” refers to a systematic, planned process that holistically plans and sequences teaching objectives, content, activities, resources, and evaluations based on specific learning theories and models to facilitate effective learning[20]. In this study, teaching design specifically refers to a comprehensive teaching process blueprint guided by the Practical Inquiry Model (PIM)[19], spanning pre-class, in-class, post-class, and cyclical iterative stages. “Teaching Strategies” refer to the sum of methods, techniques, and interactions adopted in specific teaching contexts to achieve predetermined teaching objectives[13]. In this study, teaching strategies specifically refer to the concrete methods and means employed by teachers in blended classroom practice by integrating TPACK and CL theories. It focuses on practical issues of "how to use specific technologies, pedagogical methods, and content knowledge to promote interaction, collaboration, and knowledge construction," serving as the key to vividly realizing the teaching design blueprint.

Practical Inquiry Model (PIM)

This study introduces the Practical Inquiry Model (PIM) proposed by Garrison and Vaughan[19]. This model views meaningful learning as a cyclical and progressive community-based inquiry process, comprising four interrelated phases, providing an ideal template for the phased design of blended teaching activities[21].The four phases of PIM and their applicability in blended teaching are as follows: First, the Triggering Event phase. Teachers release challenging questions, real-life cases, or cognitive conflict situations through online platforms, aiming to stimulate students' interest and curiosity, setting a cognitive anchor for the upcoming inquiry. This corresponds to the "pre-class" segment of blended teaching and is key to initiating self-directed learning. Second, the Exploration phase. Students engage in in-depth exploration around the triggering events through discussions, experiments, etc., in face-to-face classes. Teachers design diverse exploration activities during this phase, encouraging divergent thinking. Third, the Integration phase. Guided by teachers, students critically evaluate, synthesize, and conceptualize their exploration findings, forming more systematic and in-depth understandings. In-depth discussions in online forums and summaries and refinements in the classroom can serve this phase. Fourth, the Resolution phase. Learners apply newly constructed knowledge in practice, presenting learning outcomes by completing projects, solving problems, or making decisions, and receiving evaluations. This typically corresponds to "post-class" practice or presentations in the next class, closing the learning loop[19]. Applying PIM to blended teaching design ensures that online and offline activities are not isolated but jointly serve a continuous inquiry cycle aimed at deep understanding. It elevates teaching design beyond mere scheduling or content allocation to a cognitive process design supporting higher-order thinking development, particularly aligning with the characteristics of technology education that emphasize problem-solving and practical application[22].

Integrated TPACK-CL Framework

To comprehensively assess teachers' ability to integrate technology, pedagogy, and content in blended teaching, and to highlight collaborative practices in technology education, this study integrates the TPACK with CL theory, forming the TPACK-CL analytical framework.The TPACK framework reveals the complex interactive structure of knowledge required for teachers to successfully integrate technology into teaching. It comprises seven core dimensions: three foundational knowledge bases—Technology Knowledge (TK), Content Knowledge (CK), and Pedagogical Knowledge (PK); three intersectional knowledge bases formed by their pairwise interactions—Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), and Technological Pedagogical Knowledge (TPK); ultimately converging into the integrative TPACK[23]. This framework indicates that excellent blended teaching strategies do not involve applying technology in isolation but require teachers to flexibly judge: which technology is most suitable for presenting specific subject content, and which pedagogical method can most effectively utilize that technology to support students' learning of that content[24].

Meanwhile, Collaborative Learning (CL) is a crucial teaching strategy for cultivating teamwork and complex problem-solving abilities in the technology field[25]. It emphasizes structured positive interdependence, individual accountability, promotive interaction, and other elements for co-constructing knowledge within groups. In blended environments, collaboration can span online asynchronous discussions and offline synchronous activities, placing higher demands on teachers' abilities to design tasks, manage processes, and evaluate collaborative outcomes[26].Integrating CL concepts into the TPACK framework means that when examining teaching strategies, we focus not only on how teachers design general teaching activities but also on how they utilize TPACK knowledge to design and facilitate technology-enhanced collaborative learning activities. For example, how teachers select collaborative editing tools to support group projects or use social networking technologies to sustain interaction within a collaborative community.

Limitations of Existing Measurement Tools

Although research on blended teaching is increasingly abundant, standardized tools specifically for systematically assessing teachers' teaching design and strategy levels still have notable limitations. Firstly, existing tools mostly focus on a single perspective. One category of tools focuses on general technology acceptance, teacher self-efficacy, or digital literacy. Although they involve technological factors, they are not tightly embedded within specific teaching process design models, lacking measurement of the phased cognitive processes revealed by PIM. Another category of tools might be developed based on a specific teaching model, but their theoretical foundation is often narrow, failing to simultaneously encompass the complete knowledge system from macro-design to micro-strategy, particularly lacking effective measurement of the deep integration degree of various knowledge types within the TPACK framework, and even less frequently incorporating collaborative learning as a core strategic dimension for integrated investigation.

Secondly, most scales pursue generalizability and fail to adequately consider the unique needs of technology program education. Teaching in the technology field emphasizes practicality, tool use, project orientation, and problem-solving. The design logic and strategy choices for its blended teaching inevitably differ from those in general education or humanities disciplines. For instance, pedagogical knowledge related to specific technologies like virtual simulation software or programming collaboration platforms, and strategies for guiding students through technology project collaboration, are difficult to adequately represent in general scales. Currently, few measurement tools are guided by the aforementioned integrated PIM and TPACK-CL framework and specifically tailored for the practical context of technology education.

METHOD

This section elaborates on the systematic methods used in this study to develop and validate the "Blended Teaching Design and Strategy Scale for Technology Programs." The entire research follows a rigorous scale development paradigm, integrating qualitative and quantitative research methods to ensure the tool's theoretical soundness and psychometric quality.

Research Design

This study employs an explanatory sequential mixed-methods design[27], divided into two phases: First, through qualitative research, in-depth interviews were conducted with teachers to understand the concrete practical manifestations of blended teaching design and strategies in the technology education field, providing a descriptive basis for subsequent scale item generation. Subsequently, based on the qualitative findings, quantitative research was conducted using a questionnaire survey with teachers, aiming to perform item purification, explore factor structures, and validate the model of the initially developed scale through large-sample data. This design leverages the strengths of both methods: the qualitative phase explores depth, defines connotations, and provides ecological validity for the scale; the quantitative phase tests structure, validates reliability and validity, ensuring the scale's scientific rigor and generalizability [28].

Research Procedure

The research procedure follows the standardized steps of scale development, primarily comprising the following four stages:

(1) Item Pool Generation

Theory-driven items were initially derived from the integrated PIM and TPACK-CL framework, mapping each theoretical dimension to observable teaching behaviors. To enhance ecological validity, semi-structured interviews were conducted with 10 technology teachers who had over three years of blended teaching experience. Each interview lasted 45-60 minutes and was transcribed verbatim. Thematic analysis using MAXQDA software identified context-specific practices and localized expressions not captured by the theoretical framework. This dual-source approach generated an initial pool of 65 items, combining 53 theory-driven items with 12 empirically-derived items.

(2) Content Validity and Face Validity Testing

Three domain experts including a teaching administrator, a senior technology teacher, and an educational technology researcher conducted multi-round reviews evaluating item relevance, clarity, and classification accuracy. Items were revised based on expert feedback, with semantically overlapping items merged and abstract terms supplemented with concrete examples. The item count was reduced to 50. Subsequently, 12 target teachers' pilot-tested the questionnaire, providing feedback on wording comprehensibility and cultural appropriateness. Language was refined based on their input to ensure clarity for Chinese teachers.

(3) Internal Consistency Reliability Testing and Item Purification

A survey of 224 teachers from three polytechnics was conducted. Item analysis employed Corrected Item-Total Correlation, with values below 0.40 considered for deletion. Two items in the teaching strategy subscale showed low CITC values. Deletion of TPK4 significantly improved its dimension's alpha from 0.781 to 0.802, leading to its removal. TPACK4 was temporarily retained due to theoretical importance. After purification, 48 items were retained. Cronbach's alpha for the design subscale was 0.899 and for the strategy subscale 0.889, indicating excellent internal consistency.

(4) Construct Validity Testing

Exploratory Factor Analysis (EFA) with Principal Component Analysis and Varimax rotation was performed on the 48 items. The design subscale revealed a clear four-factor structure explaining 65.76% variance, with all items loading above 0.50 on their intended dimensions. The strategy subscale revealed an eight-factor structure explaining 70.51% variance, confirming the TPACK-CL framework. Confirmatory Factor Analysis (CFA) using AMOS validated these structures, with fit indices meeting recommended thresholds. Convergent validity was established with all CR values above 0.70 and AVE values above 0.50 after deleting TPACK4. Discriminant validity was confirmed using the Fornell-Larcker criterion.

Participants

The research was conducted at three polytechnics in Guangdong Province, China. These three polytechnics are all oriented towards science and engineering, are national model institutions, and possess favorable blended teaching environments.For the qualitative interviews, purposive sampling was used to select 10 teachers from the target institutions who had over three years of blended teaching experience and were designated as "blended teaching coordinators" for semi-structured interviews. All participants provided informed consent.For the quantitative survey, random sampling was employed. From the entire faculty of the technology-focused colleges within the target institutions, 230 teachers were surveyed, yielding 224 valid questionnaires. This relatively large sample size was necessary for subsequent EFA and CFA to validate the scale's construct validity. Researchers without sufficient experience in such analyses should select a sample size greater than 200 to obtain more reliable results in their studies [29][30].

Instrument

The core outcome of this study is the self-developed "Blended Teaching Design and Strategy Scale for Technology Programs." The final scale comprises two subscales, containing a total of 48 items, all using a five-point Likert scale.

(1) Blended Teaching Design Subscale

Developed based on the PIM [19], it includes four dimensions: Triggering Event, Exploration, Integration, and Resolution, with a total of 20 items. It measures the frequency or extent to which teachers plan and organize learning activities at each stage.

(2) Blended Teaching Strategy Subscale

Developed based on the integrated TPACK-CL framework[31][32], it includes eight dimensions: Technology Knowledge (TK), Content Knowledge (CK), Pedagogical Knowledge (PK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), Technological Pedagogical and Content Knowledge (TPACK), and Collaborative Learning (CL), with a total of 28 items. It measures the frequency or extent to which teachers integrate and apply various types of knowledge and organize collaborative learning in blended teaching. All items underwent a rigorous development and revision process.

Data Analysis

Multiple statistical software packages were used for data analysis:

(1) Qualitative Data Analysis

Interview recordings were transcribed verbatim. A hybrid thematic analysis combining deductive and inductive approaches was performed using MAXQDA software. Deductive coding based on the PIM and TPACK-CL frameworks was applied first, followed by inductive coding to capture emergent themes from teachers' experiences. This process verified theoretical constructs and supplemented them with context-specific practices.

(2) Quantitative Data Analysis

Quantitative analysis was conducted using SPSS 27 and AMOS 26. Item analysis employed CITC, with items below 0.40 considered for deletion. Internal consistency was assessed using Cronbach's alpha, with values above

0.70 considered acceptable. Exploratory Factor Analysis (EFA) with Principal Component Analysis and Varimax rotation was performed, extracting factors with eigenvalues >1.0. Items with factor loadings below 0.50 or cross-loadings above 0.40 were considered for deletion.

CFA was conducted to validate the factor structure. Model fit was evaluated using multiple indices: $\chi^2/df < 3.0$, RMSEA < 0.08, CFI > 0.90, TLI > 0.90. Convergent validity was assessed through standardized factor loadings (>0.50), Composite Reliability (CR > 0.70), and Average Variance Extracted (AVE > 0.50). Discriminant validity was examined using the Fornell-Larcker criterion, requiring that the square root of AVE for each construct exceed its correlations with other constructs.

RESULTS

Following the research procedure outlined in Chapter 3, this section reports the results of each stage of the blended teaching design and strategy scale development and validation.

Item Pool Generation

The initial item pool was generated by integrating both theoretical and empirical sources. First, based on the integrated theoretical framework established in the literature review—namely, the four phases of the PIM and the eight core elements of the TPACK-CL framework—theory-driven items were systematically derived. This process generated 23 initial items for the PIM section and 42 initial items for the TPACK-CL section.

Second, to enhance the scale's practical validity in the technology education context, semi-structured interviews were conducted with 10 technology field teachers. A hybrid thematic analysis was performed on the interview transcripts. The analysis identified key behavioral descriptions and localized expressions from teachers' practices. Based on these qualitative findings, the theory-driven items were supplemented and contextually revised, resulting in the addition of 12 key items derived from practice.The final initial item pool comprised a total of 65 items.

Content Validity and Face Validity Testing

The item pool underwent two rounds of rigorous validity testing. Content validity testing involved three domain experts conducting multiple rounds of independent reviews. Experts provided revision suggestions based on item relevance to the construct definition, clarity of expression, and accuracy of classification. Major revisions included: merging semantically overlapping items (e.g., "assigning tasks" and "introducing the next class"), supplementing abstract terms with concrete examples (e.g., specifying "technology" as "animation and simulation software"), and optimizing instructions and formatting. Based on expert feedback, the total number of items was refined from 65 to 50, significantly enhancing the representativeness and logical coherence of the content.

Subsequently, face validity testing invited 12 university teachers with blended teaching experience to pilot-test the questionnaire and participate in interviews. Based on their feedback, the item phrasing was optimized to better align with the language habits of Chinese teachers, such as changing "before face-to-face class" to "pre-class", and correcting potentially ambiguous sentences. The revised scale achieved good comprehensibility and acceptability among the target teacher group. Following content and face validity testing, the total number of items was refined to 50. The specific dimensions, items, and numbers are shown in Table 4.1. ：

Table 4.1: Blended Teaching Design and Strategy Scale for Technology Programs

Blended Teaching Design Subscale		
Dimensions	**Codes**	**Items**
Triggering Event (TE)	TE1	1. Before face-to-face class, I release relevant teaching videos, micro-lessons, etc. for students to preview.

	TE2	2. Before face-to-face class, I issue related tasks to guide students to conduct self-study before the formal class.
	TE3	3. Before face-to-face class, I use the online teaching platform to present the problems that need to be solved by students as preparation.
	TE4	4. Before face-to-face class, I encourage students to use the chat/forum features to ask me questions.
	TE5	5. Before face-to-face class, I release pre-class quizzes to understand students' background knowledge of the topic.
Exploration (EP)	E1	6. During face-to-face class, I guide students to explore the questions released before class.
	E2	7. During face-to-face class, I flexibly switch between online and offline teaching methods.
	E3	8. During face-to-face class, I diagnose students' mistakes and cultivate critical dialogue.
	E4	9. During face-to-face class, I adopt various technical approaches to provide students with opportunities to explore problems.
	E5	10. During face-to-face class, I encourage students to ask questions regarding the topics.
Integration (IG)	I1	11. After face-to-face teaching, I organize students to conduct further exploration on the online teaching platform.
	I2	12. After face-to-face teaching, I use communication technology to organize students for critical discussions.
	I3	13. After face-to-face teaching, I assess students and provide personalized guidance.
	I4	14. Between two face-to-face teaching sessions, I assign new collaborative projects to students on the online teaching platform.
	I5	15. Between two face-to-face teaching sessions, I collect student feedback through the online platform and adjust strategies in a timely manner.
Resolution (RS)	R1	16. In the next face-to-face class, I help students overcome the difficulties in their studies.
	R2	17. In the next face-to-face class, I provide students with more practical opportunities.
	R3	18. In the next face-to-face class, I organize students to have critical discussions and evaluate the feasibility of possible solutions.
	R4	19. In the next face-to-face class, I organize students to give presentation reports on the solutions.
	R5	20. In the next face-to-face class, I evaluate students' task completion and organize peer and self-assessments among students.

INTERNATIONAL JOURNAL OF RESEARCH AND INNOVATION IN SOCIAL SCIENCE (IJRISS)
ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue III March 2026

Blended Teaching Design Subscale

Dimensions	**Codes**	**Items**
Technological Knowledge (TK)	TK1	21. I can use technology to find the information resources I need.
	TK2	22. I will pay attention to the latest developments of important new technologies.
	TK3	23. I can help students solve technical problems.
Content Knowledge (CK)	CK1	24. I have sufficient knowledge to teach my subject.
	CK2	25. I am capable of creating teaching materials that align with the curriculum standards.
	CK3	26. I can determine the scope of the concepts to be taught in my classroom.
Pedagogical Knowledge (PK)	PK1	27. I can select specific teaching strategies based on specific content.
	PK2	28. I can adjust teaching methods according to students' performance.
	PK3	29. I know how to organize and maintain classroom order.
	PK4	30. I know how to evaluate students' performance in class.
Pedagogical Content Knowledge (PCK)	PCK1	31. I know how to select effective teaching methods to guide students in thinking and learning in the subject I teach.
	PCK2	32. I can help students notice the connections between various possible concepts in the course.
	PCK3	33. I know how to choose appropriate teaching strategies to teach difficult points.
	PCK4	34. I can select suitable teaching methods based on students' learning needs.
Technological Content Knowledge (TCK)	TCK1	35. I could use appropriate technologies to help students understand the subject content.
	TCK2	36. I could teach students to use relevant software to enhance their learning outcomes.
	TCK3	37. I could employ multimedia tools to help students understand abstract concepts more intuitively.
	TCK4	38. I could use technology to create online resources for my subject.
Technological Pedagogical Knowledge (TPK)	TPK1	39. I could select appropriate technologies to enhance students' learning outcomes in a class.
	TPK2	40. I could think critically about the application methods and effects of technologies.
	TPK3	41. I know how to use technology to manage online learning environments.
	TPK4	42. I can use technology to conduct course data analysis.

Technological Pedagogical and Content Knowledge (TPACK)	TPACK1	43. I could use technology to predict students' understanding of a particular topic .
	TPACK2	44. I could choose technologies that enhance what I teach, how I teach, and what students learn.
	TPACK3	45. I know how to use technology to create content representations that go beyond textbook knowledge.
	TPACK4	46. I can provide leadership in helping others to coordinate the use of content, technologies, and teaching approaches in my college.
Collaborative Learning (CL)	CL1	47. I design cooperative tasks based on the course content and learning objectives.
	CL2	48. I will focus on cultivating students' teamwork abilities and communication skills.
	CL3	49. I organize various group activities for students.
	CL4	50. After solving problems together, I will guide the group or group members to share their experiences.

Internal Consistency Reliability Testing and Item Purification

Following the validity tests, the researcher collected 224 valid questionnaires from the target polytechnics for item analysis and reliability testing. Consistency testing and item purification were conducted on the revised 50-item scale, with specific data presented in Tables 4.2 and 4.3.First, the Corrected Item-Total Correlation (CITC) was analyzed to assess the correlation of each item with the total score of the remaining items. Using the criterion of CITC > 0.4[33], most items met the requirement. However, two items from the teaching strategies subscale; TPK4 and TPACK4 had CITC values of 0.359 and 0.391, respectively, slightly below the threshold. Subsequently, reliability was assessed by calculating Cronbach's alpha coefficients, and the decision to retain or delete items was further informed by examining the change in the alpha coefficient if a specific item was deleted[34]. Analysis revealed that deleting TPK4 significantly increased its dimension's alpha coefficient from 0.781 to 0.802, indicating poor item quality, leading to its deletion. Deleting TPACK4 did not result in a significant change in its dimension's alpha coefficient; considering its theoretical importance, it was temporarily retained for further examination in subsequent factor analysis.

After this purification round, the total number of scale items was adjusted to 48. The overall alpha coefficient for the Blended Teaching Design subscale (20 items) was 0.899, with dimension coefficients ranging from 0.829 to 0.878. The overall alpha coefficient for the Blended Teaching Strategy subscale (28 items) was 0.889, with dimension coefficients ranging from 0.775 to 0.876. All coefficients exceeded the recommended threshold of 0.70, indicating excellent internal consistency reliability for the scale.

Table 4.2: Reliability results of the blended teaching design instrument

Blended Teaching Design Subscale		
Dimensions	**Codes**	**Items**
Triggering Event (TE)	TE1	51. Before face-to-face class, I release relevant teaching videos, micro-lessons, etc. for students to preview.
	TE2	52. Before face-to-face class, I issue related tasks to guide students to conduct self-study before the formal class.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue III March 2026

	TE3	53. Before face-to-face class, I use the online teaching platform to present the problems that need to be solved by students as preparation.
	TE4	54. Before face-to-face class, I encourage students to use the chat/forum features to ask me questions.
	TE5	55. Before face-to-face class, I release pre-class quizzes to understand students' background knowledge of the topic.
Exploration (EP)	E1	56. During face-to-face class, I guide students to explore the questions released before class.
	E2	57. During face-to-face class, I flexibly switch between online and offline teaching methods.
	E3	58. During face-to-face class, I diagnose students' mistakes and cultivate critical dialogue.
	E4	59. During face-to-face class, I adopt various technical approaches to provide students with opportunities to explore problems.
	E5	60. During face-to-face class, I encourage students to ask questions regarding the topics.
Integration (IG)	I1	61. After face-to-face teaching, I organize students to conduct further exploration on the online teaching platform.
	I2	62. After face-to-face teaching, I use communication technology to organize students for critical discussions.
	I3	63. After face-to-face teaching, I assess students and provide personalized guidance.
	I4	64. Between two face-to-face teaching sessions, I assign new collaborative projects to students on the online teaching platform.
	I5	65. Between two face-to-face teaching sessions, I collect student feedback through the online platform and adjust strategies in a timely manner.
Resolution (RS)	R1	66. In the next face-to-face class, I help students overcome the difficulties in their studies.
	R2	67. In the next face-to-face class, I provide students with more practical opportunities.
	R3	68. In the next face-to-face class, I organize students to have critical discussions and evaluate the feasibility of possible solutions.
	R4	69. In the next face-to-face class, I organize students to give presentation reports on the solutions.
	R5	70. In the next face-to-face class, I evaluate students' task completion and organize peer and self-assessments among students.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue III March 2026

Blended Teaching Design Subscale		
Dimensions	**Codes**	**Items**
Technological Knowledge (TK)	TK1	71. I can use technology to find the information resources I need.
	TK2	72. I will pay attention to the latest developments of important new technologies.
	TK3	73. I can help students solve technical problems.
Content Knowledge (CK)	CK1	74. I have sufficient knowledge to teach my subject.
	CK2	75. I am capable of creating teaching materials that align with the curriculum standards.
	CK3	76. I can determine the scope of the concepts to be taught in my classroom.
Pedagogical Knowledge (PK)	PK1	77. I can select specific teaching strategies based on specific content.
	PK2	78. I can adjust teaching methods according to students' performance.
	PK3	79. I know how to organize and maintain classroom order.
	PK4	80. I know how to evaluate students' performance in class.
Pedagogical Content Knowledge (PCK)	PCK1	81. I know how to select effective teaching methods to guide students in thinking and learning in the subject I teach.
	PCK2	82. I can help students notice the connections between various possible concepts in the course.
	PCK3	83. I know how to choose appropriate teaching strategies to teach difficult points.
	PCK4	84. I can select suitable teaching methods based on students' learning needs.
Technological Content Knowledge (TCK)	TCK1	85. I could use appropriate technologies to help students understand the subject content.
	TCK2	86. I could teach students to use relevant software to enhance their learning outcomes.
	TCK3	87. I could employ multimedia tools to help students understand abstract concepts more intuitively.
	TCK4	88. I could use technology to create online resources for my subject.
Technological Pedagogical Knowledge (TPK)	TPK1	89. I could select appropriate technologies to enhance students' learning outcomes in a class.
	TPK2	90. I could think critically about the application methods and effects of technologies.
	TPK3	91. I know how to use technology to manage online learning environments.

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	TPK4	92. I can use technology to conduct course data analysis.
Technological Pedagogical and Content Knowledge (TPACK)	TPACK1	93. I could use technology to predict students' understanding of a particular topic .
	TPACK2	94. I could choose technologies that enhance what I teach, how I teach, and what students learn.
	TPACK3	95. I know how to use technology to create content representations that go beyond textbook knowledge.
	TPACK4	96. I can provide leadership in helping others to coordinate the use of content, technologies, and teaching approaches in my college.
Collaborative Learning (CL)	CL1	97. I design cooperative tasks based on the course content and learning objectives.
	CL2	98. I will focus on cultivating students' teamwork abilities and communication skills.
	CL3	99. I organize various group activities for students.
	CL4	100. After solving problems together, I will guide the group or group members to share their experiences.

Table 4.3: Reliability results of the blended teaching strategies instrument

Construct Dimension	**Items**	**CITC**	**Cronbach'S Alpha if Item Deleted**	**Total Cronbach's Alpha for the Dimension**
Technological Knowledge	TK1	0.458	0.737	0.801
	TK2	0.448	0.704	
	TK3	0.514	0.745	
Content Knowledge	CK1	0.472	0.682	0.790
	CK2	0.440	0.75	
	CK3	0.482	0.712	
Pedagogical Knowledge	PK1	0.523	0.831	0.865
	PK2	0.591	0.834	
	PK3	0.484	0.819	
	PK4	0.546	0.826	
Pedagogical Content Knowledge	PCK1	0.508	0.833	0.876
	PCK2	0.473	0.837	
	PCK3	0.491	0.851	
	PCK4	0.461	0.843	

Technological Content Knowledge	TCK1	0.459	0.784	0.832
	TCK2	0.511	0.812	
	TCK3	0.524	0.792	
	TCK4	0.494	0.761	
Technology Pedagogical Knowledge	TPK1	0.612	0.707	0.781
	TPK2	0.562	0.705	
	TPK3	0.518	0.703	
	~~TPK4~~	0.359	0.802	
Technological Pedagogical and Content Knowledge	TPACK1	0.528	0.679	0.775
	TPACK2	0.524	0.696	
	TPACK3	0.419	0.733	
	TPACK4	0.391	0.774	
Collaborative Learning	CL1	0.504	0.793	0.840
	CL2	0.467	0.803	
	CL3	0.472	0.800	
	CL4	0.473	0.796	

Construct Validity Testing

Construct validity was examined through Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA).

Exploratory Factor Analysis

First, EFA was conducted on the 48 purified items. Bartlett's Test of Sphericity was significant, and the Kaiser-Meyer-Olkin (KMO) measures (Design subscale = 0.905; Strategy subscale = 0.842) indicated that the data were highly suitable for factor analysis[35]. Principal Component Analysis with Varimax rotation was employed, extracting factors based on eigenvalues greater than 1. The results clearly demonstrated as shown in Table 4.4, the teaching design subscale successfully extracted four common factors, explaining a cumulative variance of 65.76%. All items loaded onto their predetermined dimensions "Triggering Event," "Exploration," "Integration," and "Resolution" with factor loadings > 0.5 and no significant cross-loadings, fully aligning with the PIM theoretical structure[29].

Table 4.4: The Rotated Component Matrix of the blended teaching design instrument

Items	**Component**			
	1	**2**	**3**	**4**
E3	0.804			
E1	0.79			

E5		0.773			
E4		0.769			
E2		0.757			
R5			0.833		
R1			0.792		
R4			0.791		
R3			0.757		
R2			0.701		
I2				0.808	
I1				0.794	
I5				0.787	
I4				0.785	
I3				0.768	
TE3					0.788
TE5					0.757
TE2					0.714
TE1					0.713
TE4					0.627
Rotation Sums of Squared Loadings	Total	3.411	3.321	3.31	3.11
	% of Variance	17.055	16.607	16.548	15.552
	Cumulative %	17.055	33.662	50.21	65.762
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 6 iterations.					

As shown in Table 4.5, the teaching strategy subscale successfully extracted eight common factors, explaining a cumulative variance of 70.51%. The items clearly clustered onto their predetermined dimensions within the TPACK-CL framework, validating the eight core elements of the theoretical structure.

Table 4.5: The Rotated Component Matrix of the blended teaching strategy instrument

Items	**Component**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
PCK1	0.841							

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PCK4	0.836							
PCK2	0.831							
PCK3	0.806							
PK3		0.852						
PK1		0.807						
PK4		0.805						
PK2		0.756						
TCK4			0.817					
TCK1			0.802					
TCK3			0.766					
TCK2			0.73					
CL4				0.802				
CL2				0.798				
CL1				0.792				
CL3				0.79				
TPACK3					0.784			
TPACK1					0.763			
TPACK2					0.755			
TPACK4					0.676			
TK2						0.834		
TK1						0.799		
TK3						0.781		
CK1							0.82	
CK2							0.789	
CK3							0.788	
TPK3								0.806
TPK2								0.77
TPK1								0.753

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Rotation Sums of Squared Loadings	Total	3.014	2.889	2.779	2.777	2.504	2.222	2.160	2.105
	% of Variance	10.392	9.961	9.584	9.577	8.633	7.661	7.448	7.257
	Cumulative %	10.392	20.353	29.937	39.514	48.148	55.808	63.256	70.513
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 6 iterations.									

Confirmatory Factor Analysis

Subsequently, CFA was conducted on the structures obtained from EFA. Measurement models were constructed using AMOS software, and the fit indices indicated good model-data fit:For the teaching design model, the fit indices were: $\chi^2/df = 1.025$, which is well below the recommended threshold of 3.0; RMSEA = 0.011, which is below the conservative cutoff of 0.05 for excellent fit; CFI = 0.998 and TLI = 0.998, both exceeding the recommended value of 0.95 for excellent fit. These indices collectively indicate that the four-factor model of blended teaching design fits the data exceptionally well.

For the teaching strategy model, the fit indices were: $\chi^2/df = 1.126$, which is below the recommended threshold of 3.0; RMSEA = 0.024, which is below the conservative cutoff of 0.05; CFI = 0.983 and TLI = 0.981, both exceeding the recommended value of 0.95. Although the chi-square value was significant ($p < 0.001$), which is common with larger sample sizes, the other fit indices all met or exceeded the recommended thresholds, indicating that the eight-factor model of blended teaching strategy demonstrates good model fit. The measurement models are shown in Figures 4.1 and 4.2.

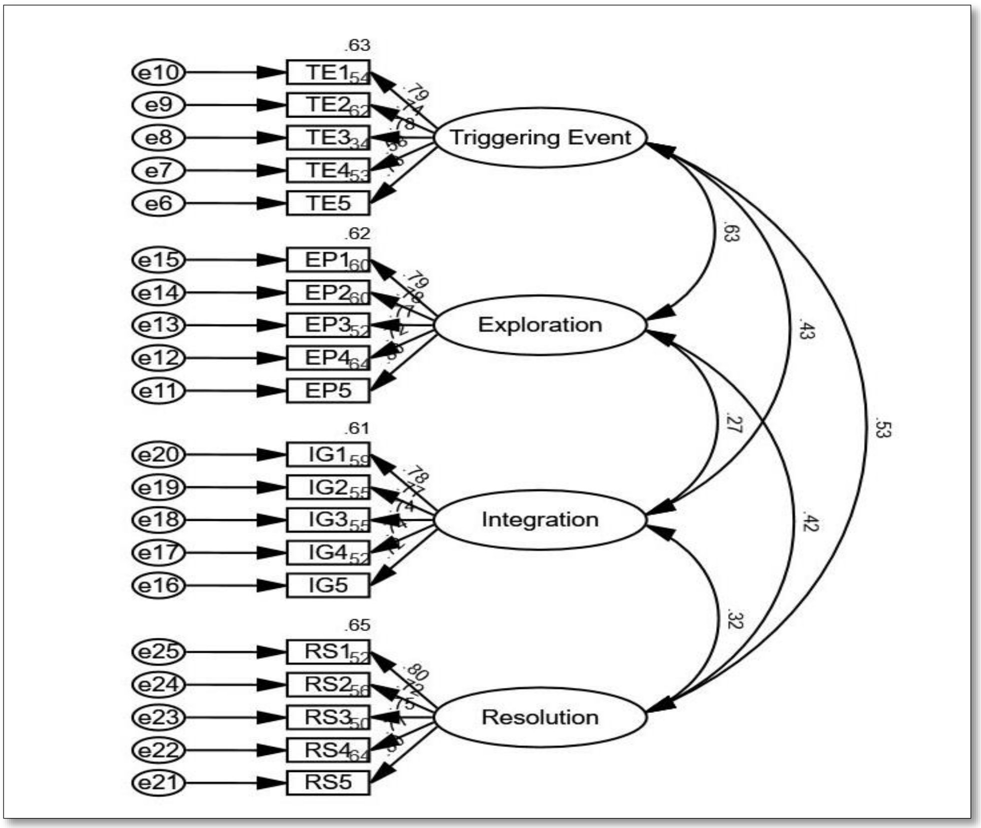

Figure 4.1: Confirmatory factor analysis measurement model for the blended teaching design instrument

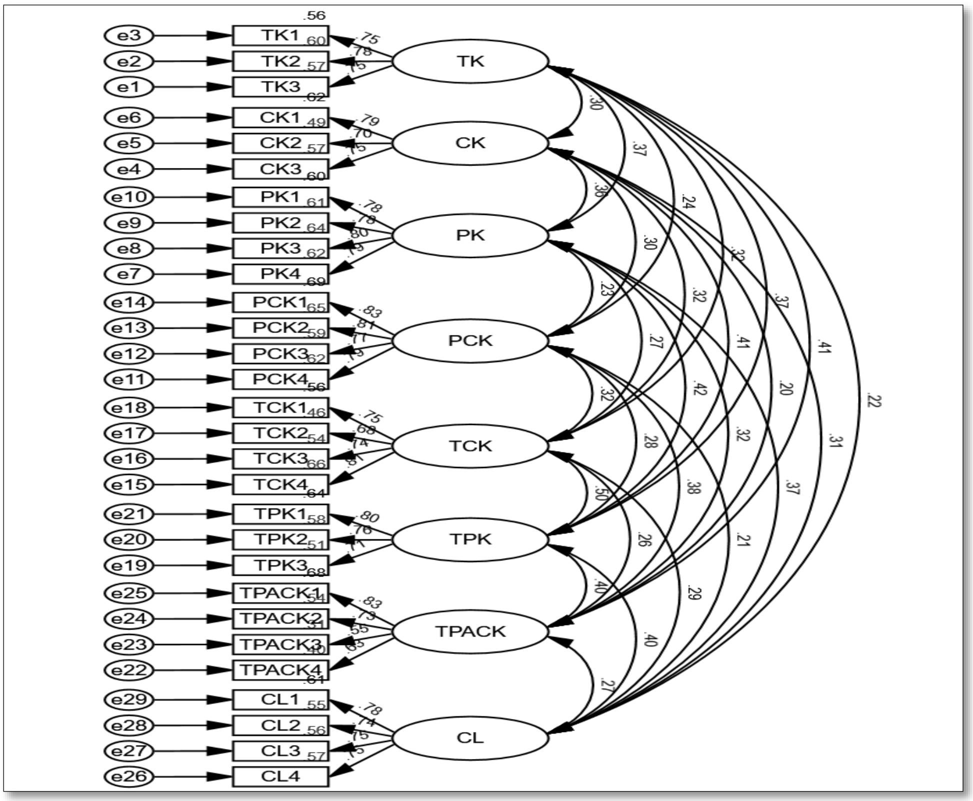

Figure 4.2: Confirmatory factor analysis measurement model of the blended teaching strategy instrument

Tables 4.6 and 4.7 present the convergent validity of the two subscales[36]. All items had standardized factor loadings greater than 0.50 (ranging from 0.554 to 0.889). Composite Reliability (CR) values for all dimensions were above 0.70. Average Variance Extracted (AVE) values were above 0.50 for all dimensions, except for the TPACK dimension, whose initial AVE was slightly low at 0.482. After deleting the low-loading item TPACK4, the AVE for the TPACK dimension increased to 0.541, and the CR increased to 0.812, reaching acceptable levels. The final scale retained 28 teaching strategy items.

Table 4.6: Test of convergence validity of the blended teaching design instrument

Construct Dimension	**Items**	**Factor Loading**	**P Value**	**Combined Reliability (CR)**	**Average Variance Extraction (AVE)**
Triggering Event	TE1	0.791	***	0.848	0.530
	TE2	0.735	***		
	TE3	0.784	***		
	TE4	0.583	***		
	TE5	0.728			
Exploration	EP1	0.786	***	0.829	0.618
	EP2	0.775	***		
	EP3	0.773	***		
	EP4	0.719	***		

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	EP5	0.797			
Integration	IG1	0.783	***	0.867	0.565
	IG2	0.770	***		
	IG3	0.743	***		
	IG4	0.742	***		
	IG5	0.719			
Resolution	RS1	0.804	***	0.870	0.573
	RS2	0.722	***		
	RS3	0.746	***		
	RS4	0.706	***		
	RS5	0.801			

Table 4.7: Test of convergence validity of the blended teaching strategy instrument

Construct Dimension	**Items**	**Factor Loading**	**P Value**	**Combined Reliability (CR)**	**Average Variance Extraction (AVE)**
Technological Knowledge	TK1	0.746	***	0.802	0.575
	TK2	0.776	***		
	TK3	0.753			
Content Knowledge	CK1	0.787	***	0.792	0.56
	CK2	0.703	***		
	CK3	0.753			
Pedagogical Knowledge	PK1	0.777	***	0.866	0.617
	PK2	0.778	***		
	PK3	0.798	***		
	PK4	0.789			
Pedagogical Content Knowledge	PCK1	0.829	***	0.876	0.64
	PCK2	0.809	***		
	PCK3	0.771	***		
	PCK4	0.789			

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Technological Content Knowledge	TCK1	0.751	***	0.834	0.558
	TCK2	0.680	***		
	TCK3	0.737	***		
	TCK4	0.814			
Technology Pedagogical Knowledge	TPK1	0.803	***	0.802	0.575
	TPK2	0.759	***		
	TPK3	0.711			
Technological Pedagogical and Content Knowledge	TPACK1	0.827	***	0.785	0.482
	TPACK2	0.735	***		
	TPACK3	0.631	***		
	~~TPACK4~~	0.554			
Collaborative Learning	CL1	0.779	***	0.841	0.569
	CL2	0.739	***		
	CL3	0.747	***		
	CL4	0.753			

Tables 4.8 and 4.9 show the discriminant validity of the two subscales. Using the Fornell-Larcker criterion, the square root of the AVE for each latent variable was greater than its correlations with other variables, indicating adequate discriminant validity among the dimensions[37][38].

Table 4.8: Discriminative validity test of the blended teaching design instrument

Latent Variables	**1**	**2**	**3**	**4**
1.Resolution	(0.757)			
2.Integration	0.324	(0.752)		
3.Exploration	0.419	0.272	(0.786)	
4.Triggering Event	0.528	0.431	0.628	(0.728)

Note: Diagonal elements are the root mean square of AVE values and highlighted in bold and in parentheses.

Table 4.9: Discriminative validity test of the blended teaching strategy instrument

Latent Variables	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1.CL	0.754							

2.TPACK	0.270	0.694						
3.TPK	0.398	0.398	0.758					
4.TCK	0.288	0.261	0.501	0.747				
5.PCK	0.206	0.380	0.281	0.320	0.80			
6.PK	0.373	0.322	0.420	0.273	0.226	0.785		
7.CK	0.312	0.201	0.406	0.322	0.30	0.360	0.748	
8.TK	0.215	0.413	0.367	0.319	0.24	0.365	0.301	0.758

Note: Diagonal elements are the root mean square of AVE values and highlighted in bold and in parentheses.

In summary, through a systematic development and validation process, a final measurement tool was formed, comprising a 20-item teaching design subscale and a 28-item teaching strategy subscale. The scale demonstrates good content validity, face validity, internal consistency reliability, and construct validity, making it a reliable instrument for assessing the blended teaching competencies of technology field teachers.

DISCUSSION

This study followed a rigorous scale development process, successfully constructing and validating the "Blended Teaching Design and Strategy Scale for Technology Programs." The results indicate that the scale is a measurement tool with good reliability and validity. The scale is divided into two interrelated subscales and ultimately consists of 48 items. The following discussion addresses the three research questions in depth, based on the research findings.

RQ1: How can an initial item pool for the scale be generated based on the integrated PIM and TPACK-CL framework, combined with the practical experiences of technology field teachers？

This study determined the initial item pool based on both existing theory and teacher interviews. First, based on the four phases of the PIM model and the eight core elements of the TPACK-CL framework, 65 initial items were systematically derived. The four phases of PIM provided a clear structural framework for the teaching design subscale, ensuring that the scale could comprehensively cover the entire blended teaching process. The combination of the seven dimensions of the TPACK framework and CL theory provided a comprehensive knowledge base and strategic dimensions for the teaching strategy subscale. The advantage of this theoretical integration is that it transcends previous scale designs with a single perspective, organically combining the teaching process design with the teacher's knowledge structure to form a three-dimensional assessment framework.Subsequently, through in-depth interviews with 10 technology field teachers, 12 key items derived from practice were summarized, providing important supplements to the theoretical items. These practice-generated items reflect the uniqueness of technology education. For example, expressions such as "using virtual simulation software to help students understand abstract concepts" and "organizing students for cross-group technical solution reviews" are typical behaviors of teachers in the technology field within blended teaching, content that is often difficult to capture in general scales.

RQ2: How can the initial items be purified and optimized through reliability and validity testing？

After multiple rounds of rigorous testing and revision, the final scale formed possesses good psychometric properties. Regarding content validity, following reviews by three domain experts, the total number of items was refined from 65 to 50. The main contributions of the expert review were: merging semantically overlapping items; supplementing abstract terms with concrete examples; and optimizing instructions and formatting, enhancing the overall readability of the scale. These revisions significantly improved the content representativeness and logical clarity of the scale.Regarding face validity, pilot testing feedback from 12 target teachers helped the researchers further optimize the language expressions. Based on the language habits of Chinese teachers, the items were made more accessible and understandable.

Regarding reliability testing, item purification was conducted through CITC analysis and calculation of Cronbach's alpha coefficients. The results showed that item TPK4 in the teaching strategy subscale had a CITC value of only 0.359, and deleting it increased its dimension's alpha coefficient from 0.781 to 0.802, indicating poor item quality, leading to its deletion. Although item TPACK4 had a CITC value slightly below the 0.4 threshold, the dimension's alpha coefficient did not change significantly after deletion. Considering its theoretical importance, it was temporarily retained for further examination in subsequent factor analysis. Ultimately, the overall alpha coefficient for the teaching design subscale was 0.899, and for the teaching strategy subscale was 0.889, with all dimensions alpha coefficients above the recommended threshold of 0.70, indicating excellent internal consistency reliability for the scale.

RQ3: What key factors constitute the effective blended teaching designs and teaching strategies implemented by teachers？

Through Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA), this study identified the key factors constituting the blended teaching designs and teaching strategies implemented by teachers. The research results clearly revealed a four-factor structure for the teaching design scale and an eight-factor structure for the teaching strategy scale, highly consistent with the theoretical predictions, validating the applicability of the integrated PIM and TPACK-CL framework.

In terms of teaching design, EFA successfully extracted four common factors, explaining a cumulative variance of 65.76%. CFA further confirmed this four-factor structure, with good model fit indices. This result indicates that technology field teachers, when implementing blended teaching, indeed follow a cyclical design logic from pre-class triggering, in-class exploration, post-class integration, to resolution in the subsequent class. The "Triggering Event" dimension emphasizes teachers stimulating student interest by releasing resources, posing questions, etc., which aligns with Keller's motivation theory[39], which emphasizes increasing curiosity through the use of novel methods, posing thought-provoking questions, and fostering cognitive challenges[40]. The "Exploration" dimension focuses on teachers organizing diverse inquiry activities in the classroom, guiding students into deep thinking. The "Integration" dimension focuses on post-class reflection and knowledge consolidation, helping students systematize what they have learned. The "Resolution" dimension concentrates on knowledge application and problem-solving, reflecting the characteristic of technology education that emphasizes practical ability development. The complete presentation of these four dimensions confirms the viewpoint proposed by Garrison and Vaughan[19]: meaningful blended learning requires a carefully designed cognitive inquiry process, rather than a simple online-offline superposition.

In teacher practice, the Triggering Event and Resolution dimensions are particularly noteworthy. The study found that many teachers invest significant effort in the Triggering Event phase, stimulating student learning motivation through carefully designed pre-class tasks. This supports Ustun & Tracey's[41] view that teaching design must bridge the cognitive loop between online and offline, rather than simply adding digital tools. The existence of the Resolution dimension reflects teachers' emphasis on learning outcomes, anchoring teaching in the development of student abilities, rather than merely focusing on the process of knowledge transmission. This indirectly confirming Sukirman et al.'s[42] view that "the adaptation of technology in blended teaching should be based on teaching effectiveness."

In terms of teaching strategies, EFA successfully extracted eight common factors, explaining a cumulative variance of 70.51%, with items clearly clustering onto their predetermined dimensions. CFA further confirmed this eight-factor structure. This result indicates that the strategies employed by technology field teachers in blended teaching are multi-dimensional, encompassing foundational dimensions like TK, CK, and PK; intersecting dimensions like PCK, TCK and TPK; the higher-order integrative dimension TPACK; and the overarching CL strategy.

Particularly noteworthy is the prominent performance of the PCK and TCK dimensions. The PCK dimension reflects teachers' ability to transform complex engineering principles and technical specifications into content understandable by students—the core of technology education. A teacher who can explain abstract concepts with vivid analogies or anticipate difficulties students might encounter when learning a specific technical knowledge point demonstrates good PCK. The TCK dimension reflects teachers' ability to use specific technological tools to present subject content, such as using simulation software to demonstrate circuit working principles or CAD tools to showcase 3D modeling processes. The prominence of these two dimensions indicates that in technology education, teachers need not only solid subject knowledge but also the professional ability to integrate subject knowledge with pedagogy and technology[43].

The TPK and TPACK dimensions reflect teachers' integrative thinking. TPK focuses on how teachers select appropriate technologies to support specific teaching methods, such as using online collaborative documents in collaborative learning or intelligent assessment systems for personalized feedback. TPACK embodies teachers' decision-making ability to dynamically coordinate technology, pedagogy, and content according to specific situations. The presence of these two dimensions helps distinguish whether teachers are "using technology for technology's sake" or "wisely employing technology for better learning outcomes." This flexible organizational approach confirms Mulenga & Shilongo's[1] assertion that blended teaching requires flexibility and adaptability.

The inclusion of CL as an independent strategic dimension is an important supplement to the TPACK framework. In technology programs, teamwork is the norm, not the exception. The study found that teachers generally value the design of collaborative learning, cultivating students' teamwork abilities through role allocation, task interdependence, and group peer assessment. This strategy aligns with the blended collaborative learning theory proposed by Lacaste, Cheng & Chuang[44], which posits that technology-mediated online collaboration can enhance students' participation and learning proficiency.

In summary, the key factors identified in this study not only validate the effectiveness of the theoretical framework but also provide a clear "competency map" for teacher professional development. Teachers can use these four design dimensions and eight strategy dimensions for self-diagnosis and to identify areas for improvement. Institutions can also use this framework to design more targeted teacher training programs, enhancing the overall quality of blended teaching.

Limitations And Recommendations For Further Studies

This study has several limitations that should be acknowledged. First, the sample was drawn exclusively from three polytechnics in Guangdong Province, China. While these institutions are representative of higher vocational education in this economically developed region, the geographic concentration limits the generalizability of findings to other regions with different economic development levels, educational policies, or technological infrastructure. Future research should conduct cross-validation studies with more diverse samples from different geographic regions and institutional types to establish measurement invariance.Second, the sample was limited to higher vocational institutions. The scale's applicability to other educational levels such as undergraduate engineering programs or secondary vocational schools remains untested. Future studies should examine the scale's psychometric properties across different educational contexts.

Third, although the sample size of 224 teachers was adequate for factor analysis, it may not capture the full diversity of blended teaching practices across different technology sub-disciplines. Future research with larger, more stratified samples could examine potential differences across fields such as computer science, mechanical engineering, and electrical engineering. Fourth, this study established construct validity but did not examine predictive validity. Whether higher scores on the scale predict better student learning outcomes remains to be tested. Future longitudinal studies could investigate relationships between teacher scores and student achievement, motivation, or engagement. Finally, educational technology is evolving rapidly, with new technologies such as Artificial Intelligence and Extended Reality rapidly integrating into teaching. Future revised versions of the scale could consider incorporating items related to teachers' use of intelligent tutoring systems, generative AI, or metaverse learning environments in their teaching design and strategies, to keep the tool at the forefront of the times.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue III March 2026

CONCLUSIONS

This study, based on the integrated PIM and TPACK-CL framework and following rigorous scale development procedures, successfully constructed and validated the "Blended Teaching Design and Strategy Scale for Technology Programs." Through a dual-source (theoretical and empirical) item generation strategy, an initial item pool of 65 items was formed. After multiple rounds of content validity testing, face validity testing, item analysis, and reliability testing, a final formal scale comprising 48 items was developed, including a 20-item teaching design subscale and a 28-item teaching strategy subscale. Reliability analysis showed an overall alpha coefficient of 0.899 for the teaching design subscale and 0.889 for the teaching strategy subscale, with all dimensions alpha coefficients above 0.70, indicating excellent internal consistency. Exploratory Factor Analysis and Confirmatory Factor Analysis confirmed the theoretical structure of the scale. The teaching design scale includes four dimensions; the teaching strategy scale includes eight dimensions. All dimensions demonstrated good convergent and discriminant validity, with model fit indices meeting ideal standards.The key factors identified in this study provide a scientific basis for diagnosing and enhancing teachers' blended teaching competencies. The four dimensions of teaching design outline a complete teaching process from pre-class triggering, in-class exploration, post-class integration, to resolution in the subsequent class. The eight dimensions of teaching strategy present a three-dimensional competency structure ranging from foundational knowledge to integrative abilities and collaborative strategies.

Teachers can use this framework for self-diagnosis, identifying directions for improvement. Institutions can also design more targeted teacher training programs based on this framework to enhance the overall quality of blended teaching. The scale developed in this study is an effective measurement tool with good reliability and validity, a solid theoretical foundation, and practical relevance. It not only provides a standardized instrument for relevant empirical research but also offers a clear competency map for teacher professional development, holding significant theoretical and practical value for promoting the quality of blended teaching in the technology education field. Future research should conduct cross-group validation with broader samples, examine the scale's predictive validity through longitudinal studies, and pay attention to the application of emerging technologies in teaching to continuously update and refine the measurement tool.

Declarations

Ethical Approval

This study strictly adhered to academic ethical norms and received formal approval from the Research Ethics Committee of Guangdong Polytechnic of Science and Technology prior to its commencement. To protect participant privacy, rigorous confidentiality measures were implemented. Research codes were used to replace personal information throughout data collection, raw data were secured through encrypted storage, and all potentially identifiable information was anonymized in the final reporting of results.

Informed Consent

Informed consent was obtained from all individual participants included in the study.

Conflict of Interest

The authors declare that they have no conflict of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available due to privacy and ethical restrictions.

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