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A blended learning model for creative thinking development

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ABSTRACT

Creative thinking is a critical competency in higher education in the industry 5.0 era. Although blended learning (BL) and design thinking (DT) are widely adopted, existing instructional approaches often lack explicit mechanisms for process-level quality regulation across the creative process, leading to inconsistent and insufficiently structured outcomes. To address this gap, this study develops and validates the blended learning design thinking plan-do-check-act (BLDTPDCA) learning model, which embeds the plan-do-check-act (PDCA) cycle as a stage-based quality regulation mechanism within the DT process, rather than as a separate tool. The model incorporates a task–modality alignment linking face-to-face learning with the empathize, define, and ideate stages, and online learning with the prototype and testing stages to support continuous feedback. The study employed a model development and validation design. Five experts evaluated the model using a 19-item index of item-objective congruence (IOC), indicating high content validity (IOC=0.95). The findings demonstrate that the model enables systematic, process-level quality regulation within creative learning activities. This study contributes to the literature by reconceptualizing PDCA as an embedded regulatory mechanism within DT and by providing a structured, theory-informed framework for aligning instructional processes with measurable creative thinking development in higher education.

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1. INTRODUCTION

Rapid technological advancement and digital transformation are reshaping work and everyday life. In the industry 5.0 era, creativity and technological competencies are widely recognized as high-value, fast-growing skills, as they are less susceptible to automation and robotics [1]. A lack of these skills increases the risk of reduced career opportunities amid ongoing technological change [2].

At the global level, higher education is increasingly expected to promote learner-centered, flexible, and digitally supported environments that foster creativity, collaboration, and lifelong learning. International policy frameworks emphasize human-centered competencies, particularly creative thinking, adaptability, and complex problem-solving. UNESCO highlights the need to redesign learning to support meaningful outcomes and learners' capacity to respond to technological and societal change [3]. Similarly, the OECD's education policy outlook 2025 [4] stresses policies that enhance learner agency, digital readiness, and competency-based education. At the national level, creativity and technology-related capabilities are key drivers of economic competitiveness [5]. However, reports from the World Economic Forum [2] and the

Office of the Education Council [6] indicate persistent skill gaps in Thailand, particularly in science and technology. These gaps are partly attributed to instructional practices that emphasize content transmission and memorization rather than creative thinking.

Despite increasing attention to technology-enhanced creativity in higher education, systematic instructional frameworks remain limited [7]–[10]. Design thinking (DT) supports the transformation of knowledge into tangible outcomes [11], yet in digital contexts it requires explicit linkage between knowledge, technology, and creativity. However, DT lacks mechanisms for cross-stage quality monitoring and iterative control, which may reduce the reliability of creative outputs [12]–[18].

These challenges are amplified for Generation Z learners, who expect flexible and interactive learning [19]. DT-based learning thus requires blended learning (BL) to support iterative processes [20]. However, BL and DT are often treated separately, with limited attention to process-level regulation. Although plan-do-check-act (PDCA) is widely used in quality improvement [21], it is rarely embedded in DT-based instruction. As a result, guidance on integrating delivery, creative processes, and quality regulation remains limited, while assessments continue to focus on outputs rather than process-based development [22], [23].

To address these gaps, this study develops and validates the blended learning design thinking plan-do-check-act (BLDTPDCA) model, integrating BL, DT, and PDCA to support creative thinking in higher education. DT serves as the core process, BL as the delivery mode, and PDCA as an embedded mechanism for continuous quality regulation. The study contributes by: i) reconceptualizing PDCA as an internal, stage-based regulatory mechanism within DT; ii) proposing an integrated framework linking instructional delivery, creative processes, and quality regulation; and iii) advancing process-based assessment by aligning Torrance and Guilford's dimensions with observable student artifacts. The objectives are to: i) synthesize the underlying principles; ii) develop the model; and iii) evaluate its content validity through expert review.

2. THEORETICAL AND CONCEPTUAL FOUNDATIONS

2.1. Creative thinking

Creative thinking is a key competency for 21st-century learners, supporting adaptation, problem-solving, and value creation in digital contexts [24]. It involves generating and refining ideas to produce novel and useful outcomes [25]–[30], and can be developed through flexible learning practices [31]. Torrance and Guilford define creativity through four components-fluency, flexibility, originality, and elaboration-representing the ability to generate, shift, innovate, and refine ideas [26], [32]–[35].

2.2. Creative thinking factors

Human creativity involves perception, memory, and decision-making processes that generate novel outcomes. Plsek [36] identifies attention, escape, and movement as core principles supporting divergent and convergent thinking [26], [37]. In educational contexts, creativity is also shaped by the learning environment. Online and virtual environments support self-directed learning, exploration, and experimentation through access to digital tools and resources [38], [39], while also enabling collaboration, feedback, and iterative reflection [40]–[42].

2.3. Characteristics of students in educational transformation in the digital era

Digital-era education emphasizes interactive, flexible, and personalized learning aligned with learners' characteristics [43]. Most undergraduates are Generation Z, who prefer hands-on, technology-enhanced environments that support engagement and development [18]. In contrast, traditional lecture-based instruction often reduces attention and motivation [44]. Additionally, positive learning environments that encourage interaction and active participation significantly influence Generation Z students' motivation and academic success, underscoring the need for instructional approaches aligned with their learning preferences.

2.4. Design thinking

DT is a human-centered approach that promotes creativity through inquiry, collaboration, and iterative problem-solving. It emphasizes transforming abstract knowledge into tangible outcomes through cycles of ideation, experimentation, and refinement [45], [46]. In education, DT enhances creativity and engagement by enabling learners to address authentic problems through collaborative and reflective processes [12], [47]–[49]. The DT process consists of five core stages: i) empathizing, which focuses on developing a deep understanding of users' needs; ii) defining, which synthesizes insights to clearly frame the problem; iii) ideating, which generates and evaluates diverse solution ideas based on feasibility and applicability [10]; iv) prototyping, which involves rapid development and refinement of solutions; and v) testing, which evaluates effectiveness through user feedback and informs further improvement [45], [50].

Although DT effectively supports creative ideation and problem-solving, it lacks explicit mechanisms for systematic quality regulation across stages. As a result, the quality and feasibility of student-generated solutions may vary, highlighting the need for a complementary framework to support structured evaluation and continuous improvement throughout the design process.

2.5. Deming's cycle PDCA

While DT promotes creativity through iterative exploration, it often lacks explicit mechanisms for systematic quality control and disciplined improvement across stages, leading to inconsistencies in learning outcomes [13], [18]. The PDCA cycle addresses this gap by providing a structured mechanism for continuous improvement: plan defines objectives and strategies, do implements learning activities, check evaluates outcomes against established criteria, and act refines processes based on evaluative evidence [21], [51]. In educational contexts, PDCA embeds systematic reflection and iterative validation within the learning process [52], [53], thereby strengthening the alignment between creative outputs and instructional objectives [54]. Consequently, integrating PDCA with DT enables a more controlled, quality-assured, and pedagogically reliable iterative learning process.

2.6. Blended learning

In higher education, instructional approaches that foster creativity should enable learners to analyze information, organize knowledge, produce artifacts, and systematically evaluate their work. These outcomes are supported by active learning strategies, such as brainstorming, role playing, and project-based learning, which promote the application of domain-specific knowledge to real-world problems [55]. BL defined as the integration of face-to-face and online instruction, enhances flexibility and reduces time and location constraints, making it well suited for creativity-oriented learning in digital contexts [56]. Prior studies indicate that online components typically constitute 30%–80% of instructional content in effective BL designs [57]–[59]. Within the BLDTPDCA framework, BL enables iterative engagement, collaboration, and continuous feedback, with instructors facilitating and learners actively constructing knowledge across physical and virtual environments [60]. This flexibility aligns with DT and supports embedding the PDCA cycle as a mechanism for quality control and continuous improvement.

2.7. Integrative synthesis of BLDT and PDCA for the BLDTPDCA learning model

The integration of BL, DT, and the PDCA cycle constitutes a complementary system for fostering creative thinking. BL provides a flexible, collaborative environment, while DT offers an iterative process. However, these approaches are often applied in isolation and lack process-level quality regulation. In the proposed framework, BL serves as the instructional environment, and DT operates as the core process aligned with flexibility, fluency, originality, and elaboration. The novelty of the BLDTPDCA model lies in embedding the PDCA cycle within each stage of DT as an internal regulatory mechanism. This integration introduces process-level quality control by structuring planning, implementation, evaluation, and refinement throughout the creative process, enabling continuous monitoring and iterative improvement of student-generated ideas and artifacts. Consequently, creative outputs are not only novel but also refined, feasible, and contextually appropriate. The model conceptualizes creative thinking as the outcome of interactions among BL, DT, and PDCA, with learners engaging in iterative cycles of idea generation, evaluation, and refinement, as illustrated in Figure 1.

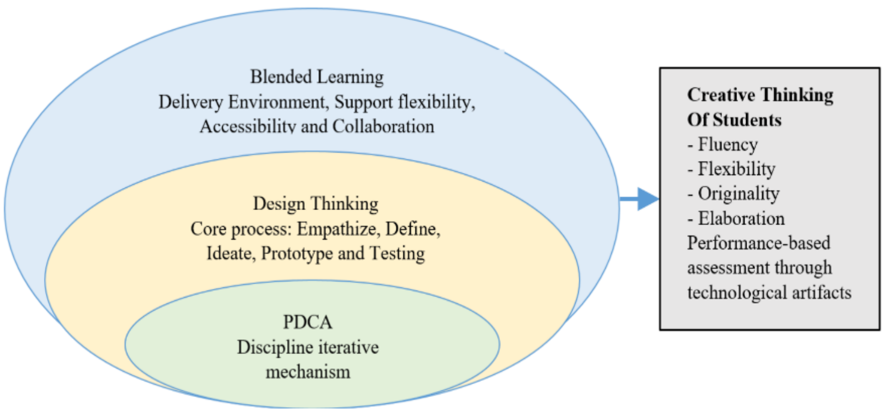

Figure 1. Conceptual framework of the BLDTPDCA model integrating BLDT and the PDCA cycle

3. METHOD

This study employed a model development and validation design to develop and validate a BL model integrating DT and the PDCA cycle. Cloud computing was selected as the instructional context due to its complexity and emphasis on higher-order thinking and system design. Tasks require transforming abstract concepts into technological prototypes through iterative refinement, aligning with DT and PDCA. Additionally, its relevance to industry 5.0 makes it suitable for examining undergraduate creative thinking in technology-enhanced environments.

3.1. Participants

Five experts were selected through purposive sampling to validate the BLDTPDCA learning model. All were based in Thailand, held doctoral degrees (Ph.D. or Ed.D.), and were either assistant professors or higher, or independent experts with at least five years of experience in curriculum development and educational technology. Their expertise ensured both theoretical rigor and practical relevance in technology-enhanced learning environments. The experts evaluated the accuracy and content validity of the model. Prior guidelines indicate that panels of three to five experts are sufficient for content validation, with five providing greater stability of item-objective congruence (IOC) estimates [61], [62]; therefore, the sample size was considered appropriate.

3.2. Research instruments

3.2.1. The BLDTPDCA learning model

The BLDTPDCA learning model served as the primary research output. The model integrates BL, DT, and the PDCA cycle and was developed for expert evaluation of its suitability and content validity.

3.2.2. The content validity evaluation form

Content validity was assessed using the IOC index. Experts rated each item on a three-point scale (+1= relevant, 0= unclear, −1= not relevant). IOC values were calculated by averaging expert ratings for each item, providing a quantitative measure of the degree of agreement regarding item relevance. Values ≥0.50 were considered acceptable, 0.50–0.79 indicated moderate congruence, and ≥0.80 indicated high content validity [61], [63], [64].

3.3. Data collection

3.3.1. Literature review and synthesis

Relevant principles, theories, concepts, and components related to BL, DT, and PDCA were systematically reviewed and synthesized to establish a theoretical foundation for model development.

3.3.2. Model design and development

The synthesized findings were used to design and develop the BLDTPDCA learning model, which consisted of three core components: input, process, and output.

3.3.3. Model validation

The preliminary BLDTPDCA model was evaluated by five experts for content validity and overall suitability using a structured assessment form administered online. Experts were provided with a detailed description of the model, including its components and conceptual framework, prior to evaluation. Each expert independently rated the items, and qualitative feedback was collected to inform model refinement.

3.4. Data analysis

3.4.1. Content validity analysis

The IOC index was calculated by averaging expert ratings for each item, providing a quantitative measure of agreement regarding item relevance. IOC values ≥0.50 were considered acceptable, 0.50–0.79 indicated moderate congruence, and ≥0.80 indicated high content validity. [61], [63], [64].

3.4.2. Model suitability analysis

Descriptive statistics (mean or M and standard deviation or SD) were used to assess the overall appropriateness of the model. The M scores were interpreted using predefined criteria, with higher values indicating greater suitability, while SD reflected the level of agreement among experts, with lower values indicating stronger consensus [65]. Combined with IOC analysis, the results provide evidence of content validity and conceptual alignment. This form of validation is widely recommended in educational design research to ensure theoretical coherence and structural appropriateness prior to empirical implementation [66].

3.5. Methodological limitations

Despite systematic validation, this study has several limitations. First, the model was evaluated by a small expert panel, which, although methodologically acceptable, may limit generalizability. Second, validation focused on content congruence rather than empirical effectiveness in authentic learning environments. Future research should employ experimental or quasi-experimental designs to examine the impact of the BLDTPDCA model on students' creative thinking outcomes.

4. RESULTS

This section reports findings from the development and expert validation of the BLDTPDCA model, emphasizing content validity and conceptual alignment among BL, DT, PDCA, and creative thinking.

4.1. Development of the BLDTPDCA learning model

The BLDTPDCA learning model was developed through a theoretical synthesis aimed at enhancing the creative thinking skills of higher education students. The model consists of three core components: input, process, and output, as illustrated in Figure 2.

4.1.1. Input component of the BLDTPDCA learning model

The input component of the BLDTPDCA model comprises three elements in Figure 2: knowledge, learners, and teacher. Knowledge refers to domain-specific content in cloud computing, including key concepts and principles, provided by the instructor and applied by learners to support problem solving. Learners actively engage in learning activities, problem solving, idea exchange, and collaboration. Teacher acts as a facilitator and coach, providing expertise, structuring activities, and designing communication and assessment strategies.

4.1.2. Process

The BLDTPDCA learning process integrates DT as the core process, the PDCA cycle as an embedded quality improvement mechanism, and BL as the delivery mode. Instruction follows a blended format (70% face-to-face, 30% online), as illustrated in Figure 2. Face-to-face sessions support the empathize, define, and ideate stages, emphasizing collaboration, discussion, and shared understanding. Online learning is applied in the prototype and test stages via a virtual platform (spatial.io), enabling extended collaboration, continuous feedback, and evaluation of prototypes based on user experience and usability. The integrated DT–PDCA process spans all five DT stages, with PDCA embedded to structure iterative cycles of planning, action, evaluation, and refinement. Instructors act as facilitators, guiding these cycles to ensure continuous improvement and process-level quality in Table 1.

4.1.3. Outputs

The outputs of the BLDTPDCA model reflect two primary learning objectives: learning achievement and creative thinking skills, as illustrated in Figure 2. Learning achievement is conceptualized as an expected output of the BLDTPDCA learning model. In future implementations, learning achievement can be assessed using a multiple-choice test administered before and after instruction, with pretest and posttest scores analyzed using a paired-samples t-test to examine learning gains, with the level of statistical significance set at 0.05. Creative thinking skills refer to students' observable performance in generating and refining ideas throughout the DT process. Based on Torrance and Guilford's framework, creative thinking is assessed across four dimensions: originality, flexibility, fluency, and elaboration. Assessment is conducted using a performance-based approach adapted from the creative thinking VALUE rubric developed by the Association of American Colleges and Universities [67]. The assessment of creative thinking skills was conducted based on the creativity framework proposed by Torrance and Guilford, using a performance-based assessment approach. The creative thinking VALUE rubric developed by the Association of American Colleges and Universities [67] was applied to systematically evaluate students' creative thinking outcomes, as presented in Table 2.

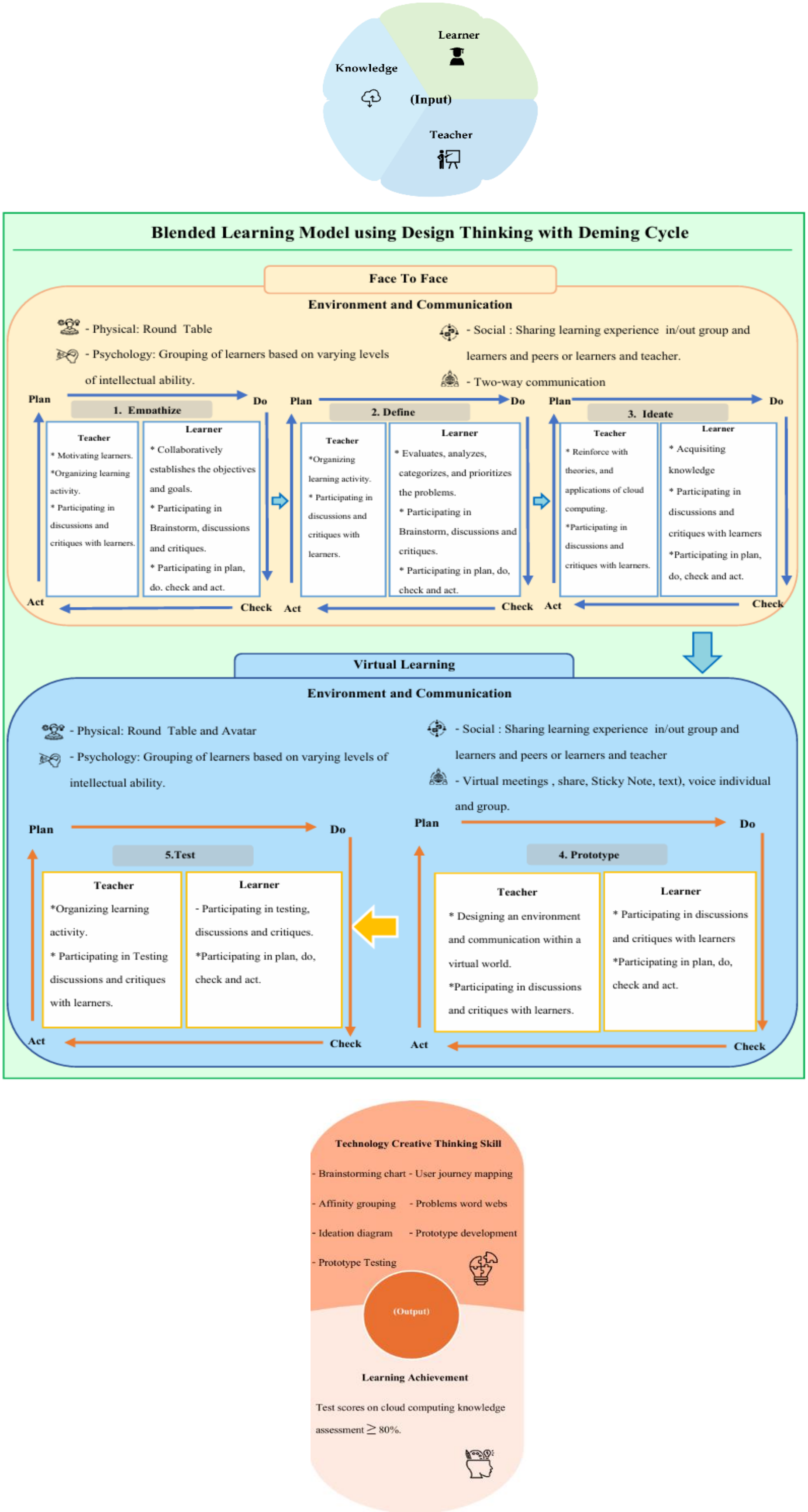

Figure 2. BLDTPDCA learning model

Table 1. BLDTPDCA process for developing creative thinking skills in higher education

DT stage	Delivery mode	Learning activities	PDCA based quality mechanism	Creative thinking outcomes
Empathize	Face-to-face	Students collaboratively define objectives and strategies and engage in time-bounded brainstorming to identify user needs and problems, supported by the development of user journey maps. Peer and instructor feedback is provided.	PDCA focuses on data adequacy, ensuring that problem and user need data are sufficient and complete. Learner's plan, review, and revise data based on feedback.	Learners demonstrate an understanding of users from multiple perspectives and openness to diverse data and experiences, reflecting the ability to shift cognitive frames and adapt perspectives within time constraints. This indicates the development of flexibility as a creative thinking skill.
Define	Face-to-face	Students analyze, categorize, and prioritize user problems and needs identified during the empathizing stage. The information is then organized and synthesized using affinity grouping to structure and connect data from diverse user perspectives. Peer and instructor feedback is provided.	PDCA emphasizes problem clarity and specificity, verifying that the problem statement is actionable for design. Iterative refinement is guided by feedback.	The expression of flexibility as a creative thinking skill is demonstrated through the development of a well-structured problem frame that can be effectively used as a foundation for generating solutions in subsequent stages.
Ideate	Face-to-face	The instructor provides foundational knowledge in cloud computing. Learners then engage in time-bounded brainstorming and apply this knowledge to generate a wide range of cloud-based technological solutions. Ideas are presented using Ideation diagrams.	PDCA evaluates feasibility and technological viability, ensuring ideas are realistic and applicable. Ideas are refined through iterative feedback.	The expression of fluency is demonstrated through the generation of multiple solution ideas, while originality is reflected in the presentation of cloud-based solutions that are distinct or novel compared to conventional approaches.
Prototype	Online	The instructor designs a virtual learning environment in which learners develop technological prototypes by applying cloud computing knowledge and present their work within the virtual environment. The prototype was reviewed by peers and instructors.	PDCA focuses on functionality and user experience (UX). Prototypes are iteratively improved based on structured feedback.	The expression of elaboration as a creative thinking skill is demonstrated through the development of technological prototypes with clear structure, comprehensive detail, and the ability to concretely represent the designed solutions and address user requirements.
Test	Online	Learners refine their technological prototypes and involve peers in testing and evaluation activities within a virtual environment to verify the effectiveness of the proposed solutions.	PDCA cycle verifies final quality and usability, guiding corrective actions and final improvements.	The expression of elaboration as a creative thinking skill is demonstrated through iterative refinement and design decision-making informed by testing results, leading to complete, high-quality prototypes that effectively address the defined problem.

Table 2. Mapping of creative thinking components based on Torrance and Guilford to the creative thinking VALUE rubric (AAC&U)

Creative thinking components (Torrance and Guilford)	Creative thinking VALUE rubric indicators (AAC&U)	Conceptual description
Originality	Innovative thinking	The ability to propose ideas that are novel, original, or distinct from conventional approaches.
	Acquiring competencies	The effective application of domain-specific knowledge to develop appropriate ideas or solutions.
Fluency	Solving problem	The ability to generate a large number of ideas or solution alternatives, reflecting continuity and ease of thinking.
Flexibility	Embracing contradictions	The ability to shift perspectives, adapt thinking, and select approaches that differ from established frameworks.
Elaboration	Connecting, synthesizing, transforming ideas	The ability to develop, expand, and articulate ideas with depth, coherence, and completeness.

4.2. Content validity of the BLDTPDCA learning model

The content validity of the BLDTPDCA model was evaluated by five experts using the IOC index, M, and SD. As shown in Table 3, the model demonstrated high content validity (M=0.95, SD=0.05), meeting the acceptance criteria for all indicators. This high level of agreement indicates strong conceptual alignment with the underlying framework, integrating BL as the instructional environment, DT as the creative process, and the PDCA cycle as a regulatory mechanism. The results further suggest that the model is structurally coherent and supports the development of creative thinking skills in higher education.

As shown in Table 4, the input and output components demonstrated very high content validity (M=1.00, SD=0.00), while the Process component also showed high validity (M=0.97, SD=0.06). The lowest score was observed for the integration of BL, DT, and PDCA within the learning process (M=0.80, SD=0.45), suggesting the need for clearer articulation of PDCA across DT stages. Expert feedback recommended strengthening quality checkpoints to enhance the transparency of PDCA as an embedded iterative quality regulation mechanism.

The strong evaluation of the Input and Output components indicates clear theoretical alignment with the development of creative thinking skills. In contrast, the slightly lower score for the Process component reflects the complexity of integrating multiple pedagogical frameworks within a unified design. This finding is consistent with prior research suggesting that DT supports ideation but requires additional mechanisms for structured evaluation and iterative refinement. Overall, the BLDTPDCA model demonstrates strong conceptual coherence, with a need for clearer articulation of PDCA integration.

Table 3. Overall evaluation results of the BLDTPDCA learning model

Overall evaluation items	M	SD	Interpretation
All components are aligned with BL DT and PDCA	1.00	0.00	Accepted
All components effectively support the BL DT and PDCA process	1.00	0.00	Accepted
The model demonstrates clear interconnections among components	0.80	0.45	Accepted
Overall appropriateness of the model	1.00	0.00	Accepted
Overall	0.95	0.05	Accepted

Table 4. Component level content validity evaluation of the BLDTPDCA learning model

Component items	M	SD	Interpretation
1. Input			
1.1 Completeness of subcomponents in the input	1.00	0.00	Accepted
1.2 Appropriateness of subcomponents in the input	1.00	0.00	Accepted
1.3 Alignment of subcomponents in the input	1.00	0.00	Accepted
1.4 Interconnection among subcomponents in the input	1.00	0.00	Accepted
Overall (Input)	1.00	0.00	Accepted
2. Process			
2.1 Alignment of the integrated learning model	1.00	0.00	Accepted
2.2 Coverage of the integrated learning model	1.00	0.00	Accepted
2.3 The relationship among BL DT and PDCA enhances learners' creative thinking skills	1.00	0.00	Accepted
2.4 Coverage of BL, DT, and PDCA stages in enhancing learners' creative thinking skills	0.80	0.45	Accepted
2.5 Appropriateness of subcomponents in the process	1.00	0.00	Accepted
2.6 Alignment of subcomponents in the process	1.00	0.00	Accepted
2.7 Interconnection among subcomponents in the process	1.00	0.00	Accepted
Overall (Process)	0.97	0.06	Accepted
3. Output			
3.1 Outputs are aligned with the learning process of the model	1.00	0.00	Accepted
3.2 Alignment of subcomponents in learning outcomes	1.00	0.00	Accepted
3.3 Appropriateness of subcomponents in learning outcomes	1.00	0.00	Accepted
3.4 Learners can achieve the intended learning outcomes in both knowledge and creative thinking skills	1.00	0.00	Accepted
Overall (Output)	1.00	0.00	Accepted

5. DISCUSSION

The BLDTPDCA model demonstrated high content validity (IOC=0.95), indicating strong theoretical coherence and alignment with creative thinking objectives. However, as the evaluation relies on expert judgment, it does not indicate implementation effectiveness. Consistent with Lynn [61] and Turner and Carlson [64], IOC values ≥0.50 indicate acceptable validity, while values near 1.00 reflect strong conceptual clarity.

At the component level, the input and output elements received the highest ratings (IOC=1.00), indicating strong alignment among knowledge content, learning environment, teacher and learner roles, and assessment within the BL framework. This finding is consistent with prior research [58], [59], which emphasizes that well-structured BL environments support active learning and the development of higher-order competencies, including creativity as conceptualized by Torrance and Guilford. This strong alignment can be explained by the task–modality design in the BLDTPDCA model. Face-to-face sessions are mainly used for the empathize, define, and ideate stages because these phases require intensive brainstorming and collaboration. In-person interaction may help students build shared problem understanding and exchange perspectives quickly. These conditions are associated with the development of fluency, flexibility, and originality in creative thinking [68], [69]. The effectiveness of this approach depends on group dynamics, facilitation quality, and students' prior collaborative experience. In the BLDTPDCA model, online learning is applied in the prototype and test stages, reducing time constraints and supporting iterative development through continuous, traceable feedback. Such feedback-rich environments enhance the completeness and clarity of student work and are expected to support the development of elaboration in creative thinking [70].

However, these benefits may vary depending on technological readiness and feedback design quality. The process component showed a slightly lower IOC (0.97), particularly for the integration of BL, DT, and PDCA (IOC=0.80), reflecting the complexity of operationalizing cross-framework integration. This finding aligns with prior research indicating that, although DT supports ideation, it often lacks explicit mechanisms for systematic quality control and disciplined iterative improvement [13], [18], [68]. Expert recommendations to clarify the role of PDCA across DT stages are theoretically grounded and consistent with prior work. PDCA is widely recognized as a structured mechanism for continuous improvement [21], [51], while stage-level quality regulation is essential to ensure that creative outputs are not only novel but also technically robust and educationally meaningful [11], [71]. The lower IOC for the process component suggests that PDCA integration, while conceptually sound, may lack clarity. Embedding PDCA across DT stages may increase procedural complexity and create tension between creative openness and process control. Rigid use may limit exploration, whereas flexible application can enhance iterative refinement and design robustness.

These findings indicate that PDCA does not inherently ensure progressive creative development, as its effectiveness depends on implementation. The lower IOC likely reflects the complexity of cross-framework integration rather than a structural weakness. Overall, the BLDTPDCA model demonstrates coherent integration of BL, DT, and PDCA, with BL as the delivery environment, DT as the core process, and PDCA as a quality regulation mechanism. This configuration addresses limitations of DT in lacking structured improvement mechanisms [13], [18], while BL supports iterative refinement and continuous feedback in technology-enhanced environments, consistent with Brisco *et al.* [20].

From a higher education policy and management perspective, the BLDTPDCA learning model also demonstrates conceptual alignment with outcome-based education (OBE). By explicitly linking intended learning outcomes, learning activities, and assessment processes, the model provides a structured pathway for embedding creative thinking as a measurable competency within technology-oriented curricula. This orientation is consistent with contemporary higher education policy directions that emphasize learner-centered education, competency-based curriculum design, and accountability for demonstrable learning outcomes in response to complex societal and technological demands [4], [72]. The integration of the PDCA cycle within the BLDTPDCA model provides a mechanism for linking instructional design with continuous quality improvement. By structuring planning, monitoring, evaluation, and refinement, it supports systematic tracking and evidence-informed improvement, aligning with higher education quality assurance frameworks emphasizing continuous enhancement and data-driven decision-making [4], [73].

From a theoretical perspective, this study advances instructional design by demonstrating how process-level quality regulation can be systematically embedded within DT-based learning. While prior research has primarily positioned DT as a framework for fostering creativity, this study reconceptualizes the PDCA cycle as an internal regulatory mechanism operating across all design stages. This integration establishes a clearer linkage between creative processes and quality assurance, addressing a gap in existing models where exploration and evaluation are often weakly connected. From a practical perspective, the BLDTPDCA model provides a structured approach for designing learning activities that promote creativity while ensuring quality control. It guides the allocation of face-to-face and online activities across DT stages and enables continuous monitoring, evaluation, and refinement through the PDCA cycle. As a result, creative thinking can be developed and assessed more systematically and measurably in higher education contexts.

Despite these findings, the lower IOC for the Process component suggests that cross-stage integration of BL, DT, and PDCA requires clearer operationalization. As validation relied on expert judgment, the model's effectiveness in practice remains untested and may depend on contextual factors such as institutional readiness, instructor expertise, and technology. Future research should employ experimental, quasi-experimental, or design-based approaches to examine its impact on creative thinking in authentic settings.

6. CONCLUSION

This study developed the BLDTPDCA model as an integrated framework combining BL, DT, and PDCA to support creative thinking in higher education. The model demonstrated high content validity and strong conceptual alignment. Theoretically, this study contributes by embedding PDCA as a process-level quality regulation mechanism within the DT process, thereby strengthening the linkage between creative processes and systematic evaluation. Practically, the model offers a structured yet flexible instructional design framework that supports interaction, iterative refinement, and performance-based assessment of creative thinking in technology-enhanced learning environments. However, the findings are limited by reliance on expert judgment rather than empirical implementation and by the relatively small expert panel. Future research should examine the effectiveness of the model through experimental or quasi-experimental studies in authentic educational contexts and explore its applicability across diverse institutional settings.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Nuttapong Prasertsung	✓	✓			✓	✓		✓	✓		✓			
Alisa Songsriwittaya	✓			✓						✓		✓		

C : **C**onceptualization	I : **I**nvestigation	Vi : **Vi**sualization
M : **M**ethodology	R : **R**esources	Su : **Su**pervision
So : **So**ftware	D : **D**ata Curation	P : **P**roject administration
Va : **Va**lidation	O : Writing - **O**riginal Draft	Fu : **Fu**nding acquisition
Fo : **Fo**rmal analysis	E : Writing - Review & **E**diting	

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest related to this research or the publication of this manuscript.

INFORMED CONSENT

Informed consent was obtained from all experts involved in this study.

ETHICAL APPROVAL

This research was reviewed and approved by the Human Research Ethics Committee of King Mongkut’s University of Technology Thonburi (KMUTT-IRB), under approval number KMUTT-IRB-COA-2025-054.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, [NP], upon reasonable request.

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