Ed Process Int J

www.edupij.com

ISSN 2147-0901 (Print), 2564-8020 (Online)

EDUCATIONAL PROCESS
INTERNATIONAL JOURNAL

Enhancing Critical and Creative Thinking Capabilities in Pre-service Teacher Education: Digital Integration and Pedagogical Innovation in Thailand's Next Normal Era

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Research Article

Cite this article: Duangngern, P., Wannapipat, W., Srikoon, S., & Kwangmuang, P. (2025). Enhancing Critical and Creative Thinking Capabilities in Pre-service Teacher Education: Digital Integration and Pedagogical Innovation in Thailand's Next Normal Era. *Educational Process: International Journal, 15*, e2025103. https://doi.org/10.22521/edupij.2025.15.103

Received February 1, 2025
Accepted March 15, 2025
Published Online March 23, 2025

Keywords: Critical-creative thinking capabilities, pre-service teacher education, digital integration, pedagogical innovation, next normal era

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Abstract

Background/purpose. The ongoing digital transformation in education has identified important areas for development in pre-service teachers' preparation to facilitate critical and creative thinking within technology-enhanced learning environments. This study investigated the readiness and implementation of creative and critical thinking skills among pre-service teachers in Thailand during the Next Normal era.

Materials/methods. The study employed a comprehensive mixed-methods sequential explanatory design, gathering data from 85 pre-service teachers and 11 faculty members across multiple higher education institutions. Quantitative data were collected through surveys and assessments, while qualitative insights were obtained through 20 in-depth interviews and four focus group discussions.

Results. The findings revealed that data analysis had emerged as the most potent capability with a strong correlation to digital tool proficiency. Project-based learning demonstrated the highest effectiveness rating, though significant implementation challenges were identified. Notable disparities in technological readiness between urban and rural settings highlighted infrastructure challenges.

Conclusion. Successful development of critical and creative thinking capabilities requires a balanced approach combining structured support systems, innovative pedagogical strategies, and technological infrastructure, while addressing the specific needs and constraints of different educational contexts. The study contributes to understanding how institutional support, pedagogical approaches, and technological integration influence the development of essential cognitive skills in teacher education.

1. Introduction

The dramatic transformation of global education has led to fundamental changes in how educational institutions prepare teachers, especially in developing critical and creative thinking capabilities (Abuhassna & Alnawajha, 2023; Olney et al., 2023). Studies by McBride et al. (2023) and Huang and Sang (2023) indicate that this shift was further accelerated by the COVID-19 pandemic, which impacted over 1.6 billion students worldwide, with 94% experiencing educational disruptions. This dramatic change has exposed significant deficiencies in the readiness of aspiring educators for technology-driven learning environments, particularly in their ability to develop essential cognitive skills (Silva et al., 2022; Wong et al., 2021). The swift shift to remote and hybrid instructional models has highlighted the urgent need for pedagogical approaches that effectively develop analytical and innovative thinking in future educators (Núñez-Canal et al., 2022).

Critical and creative thinking development has become an important focus in teacher education. Paul and Elder (2019) suggest that structured approaches combining these cognitive processes support effective teaching practices in digital classrooms. Babenko (2020) describes these competencies as interconnected, involving both analytical evaluation and creative ideation. Huang and Sang (2023) identify two aspects of critical thinking in teacher training: analytical reasoning and contextual understanding.

Despite increasing recognition of these cognitive skills, significant challenges persist in their effective implementation. Longitudinal research by Silva et al. (2022) indicates that conventional university curricula alone are insufficient in cultivating these proficiencies. Similarly, Hamid et al. (2021) found that while most novice educators exhibit moderate levels of critical and creative thinking, those with advanced cognitive skills demonstrate notably higher teaching efficacy. Additionally, studies by Wong et al. (2021) and McBride et al. (2023) emphasize the benefits of blended and experiential learning in enhancing higher-order thinking, though barriers to widespread adoption remain.

The research gap in the current literature is notable. While studies have examined various aspects of critical and creative thinking development, there is limited understanding of how these capabilities transfer across different educational contexts and cultural settings (Huang & Sang, 2023). Moreover, the long-term impact of digital competency development on teaching effectiveness requires further investigation (Silva et al., 2022), particularly concerning institutional support systems and implementation strategies (Núñez-Canal et al., 2022).

To address these gaps, this study aims to achieve the following objectives:

1. To examine the current state of critical and creative thinking capabilities among pre-service teachers in Thailand's higher education institutions during the Next Normal era

2. To analyze instructional strategies and pedagogical approaches that effectively promote critical and creative thinking capabilities in teacher education programs as perceived by faculty members

3. To develop and propose an innovative framework for enhancing critical and creative thinking capabilities in the teacher education curriculum, aligning it with Next Normal educational demands.

This study makes several important contributions to teacher education. First, it provides empirical evidence on the impact of digital pedagogical integration in enhancing analytical skills in future educators, expanding on the work of Olney et al. (2023) and Fang et al. (2021). Second, it explores the complex interplay between technological readiness, institutional infrastructure, and instructional effectiveness, building upon the findings of Chen et al. (2022) and Wu et al. (2021). Lastly, it presents a comprehensive framework for strengthening critical and creative thinking,

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addressing institutional challenges while identifying opportunities for pedagogical innovation (Zalavra et al., 2022; Tuan, 2022). Findings from this study will inform curriculum design and professional development initiatives in teacher preparation programs. By offering evidence-based strategies for enhancing these competencies, this research contributes to the broader objective of equipping educators with the necessary cognitive skills to navigate the evolving complexities of contemporary teaching in the Next Normal era.

2. Literature Review

2.1. Digital competency development in pre-service teacher education during the next normal era

Recent global events have accelerated the digital transformation of education, leading to significant changes in teacher preparation programs and emphasizing the importance of digital competency development among pre-service teachers (PSTs). This transformation necessitates a comprehensive understanding of how digital competencies are developed, assessed, and integrated into teacher education programs (Abuhassna & Alnawajha, 2023; Olney et al., 2023). The theoretical foundation for digital competency development in teacher education draws from multiple frameworks that emphasize the integration of technological, pedagogical, and content knowledge. Paul and Elder (2019) argue that systematic approaches combining critical and creative thinking are essential for developing innovative teaching practices in digital environments. This perspective is reinforced by Babenko (2020), who presents digital competency as an interdependent process requiring both evaluation and imaginative idea generation. Recent studies have significantly contributed to our understanding of digital competency development in teacher education. Huang and Sang (2023) identify two primary dimensions of digital competency: the logical dimension, focusing on technical skills and procedural knowledge, and the value dimension, emphasizing pedagogical application and contextual understanding. This dual approach demonstrates the essential balance between technical proficiency and pedagogical effectiveness in contemporary educational settings.

The transition to digital teaching environments has revealed significant challenges in implementing digital competency development programs, as highlighted by Bosch's (2022) investigation of participatory design projects, which found that PSTs engagement with digital tools is significantly influenced by institutional support structures and peer collaboration opportunities. Silva et al. (2022) further emphasize the complexity of digital competency development, whose longitudinal study revealed that conventional university curricula alone are insufficient for developing digital competencies. This finding aligns with research by Hamid et al. (2021), demonstrating that higher levels of digital competency correlate strongly with increased teaching self-efficacy. Wong et al. (2021) contribute valuable insights through their research on blended learning approaches, showing how these methods effectively promote problem-solving and higher-order cognitive skills in digital environments. The integration of technology into pedagogical practice represents a critical aspect of digital competency development, as emphasized by McBride et al. (2023), who highlight the importance of playful learning experiences in developing digital competencies.

Building upon the understanding of implementation challenges, several studies have proposed practical frameworks for competency development. Olney et al. (2023) make significant contributions by identifying essential competencies required for instructional design in open and distance learning environments, emphasizing the need for PSTs to develop skills in designing digital interventions and managing stakeholder relationships in virtual spaces. This perspective is complemented by Kim's (2021) comprehensive framework for assessing teacher design knowledge in technology-enhanced learning environments. Assessment and professional development in digital competencies present unique challenges that require innovative approaches. As Fang et al. (2021)

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presented the Collaborative Feedback-based Peer-Assessment approach, they showed that PSTs' critical thinking and digital content creation significantly improved. Chen et al. (2022) support these findings, showing that co-design activities enhance the usefulness and originality of technology-integrated instructional designs. Research by Núñez-Canal et al. (2022) identifies significant gaps in educators' digital competence, particularly in response to pandemic-driven educational changes, emphasizing the need for targeted professional development initiatives.

Contemporary research by Phodong and Jarujit (2022) reveals that structured training in digital instructional techniques substantially enhances PSTs' ability to create engaging learning experiences. This finding is supported by Ma et al. (2022), who identified six key elements contributing to successful online professional development, including TPACK self-assessment and peer interaction. Additionally, Zalavra et al. (2022) emphasize the importance of learning design representations in supporting teachers' digital competency development, highlighting preferences for visual formats and flexible frameworks. Despite extensive research in this area, several significant gaps remain that warrant further investigation. There is limited understanding of how digital competencies transfer across different educational contexts and cultural settings (Huang & Sang, 2023). The long-term impact of digital competency development on teaching effectiveness requires further investigation (Silva et al., 2022), and the relationship between digital competency and student learning outcomes in various subject areas remains understudied (Wong et al., 2021). Future research should address these gaps while considering the dynamic nature of digital education. This literature review underscores the intricate relationship between technological proficiency, pedagogical expertise, and institutional support in shaping digital competencies in teacher education. The findings suggest that a well-rounded approach—integrating structured training, hands-on experience, and ongoing professional development—is essential for fostering these skills effectively. As education continues to evolve in response to technological advancements, a deeper understanding of these interconnected factors is crucial for preparing educators to thrive in digital learning environments.

2.2. Institutional support systems and infrastructure for technology integration in teacher education programs

The successful integration of technology in teacher education programs heavily depends on institutional support systems and well-established technological infrastructure. Recent research highlights the critical role of institutional frameworks in facilitating effective technology adoption and implementation within teacher training programs. Boer and Asino (2022) conducted a comprehensive study examining the relationship between institutional support and technology integration during the COVID-19 pandemic, revealing that limited digital infrastructure and poor connectivity significantly impacted teachers' ability to develop and implement effective digital learning materials. Their findings emphasize that institutional investment in technological infrastructure serves as a fundamental prerequisite for successful digital transformation in teacher education. The significance of structured support systems becomes particularly evident in research by Sudhindra et al. (2022), who analyzed pre-engagement narratives from design education summits. Their study demonstrates that design-specific and non-design competencies play crucial roles in instructional planning, with institutional support as a critical mediating factor. The research particularly emphasizes how the COVID-19 pandemic necessitated more flexible and technology-integrated pedagogies, requiring institutions to adapt their support structures accordingly.

Furthermore, Olney et al. (2023) explored the importance of learner-centered design frameworks in professional development programs, emphasizing that institutional support should extend beyond mere technological provision to include comprehensive training and ongoing assistance. Their research reveals that institutions implementing technology integration maintain a balanced approach between infrastructure development and pedagogical support, ensuring that

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PSTs receive technical and methodological guidance. Recent studies also highlight the critical role of institutional leadership in fostering technology integration. Wong and Hughes (2022) examined how institutional support influences social cognitive motivational traits in PSTs, finding that well-structured support systems significantly enhance self-efficacy and task-value beliefs. Their research demonstrates that institutions providing comprehensive support frameworks experience higher rates of successful technology implementation and improved learning outcomes.

The quality of technical infrastructure emerges as a crucial factor in several studies. Kyza and Agesilaou (2022) identified that socio-structural conditions, including reliable technical infrastructure, significantly influence power-sharing dynamics in teacher-researcher co-design settings. Their findings suggest that institutions must invest in both physical infrastructure and support personnel to create effective learning environments. This perspective is reinforced by Lin et al. (2023), who identified technology effectiveness as one of six critical factors influencing academic performance in distance learning environments. However, research also reveals significant challenges in implementing effective support systems. Núñez-Canal et al. (2022) identified substantial gaps in institutional support structures, particularly regarding the provision of digital resources and technical assistance. Their study emphasizes the need for institutions to develop more comprehensive support frameworks that address both immediate technical needs and long-term professional development requirements. This finding aligns with research by Chan et al. (2022), who stress the importance of aligning institutional support with real-world applications and practical teaching requirements. Recent work by Castañeda and Yeoman (2023) introduces the ACAD toolkit as an institutional support mechanism, demonstrating how structured support tools can enhance educational designers' ability to develop practical learning experiences. Their research emphasizes the importance of providing institutions with concrete tools and frameworks to support technology integration efforts. Similarly, Wu et al. (2021) highlight the significance of technology-enhanced training environments in fostering STEM learning design expertise, suggesting that institutions should invest in specialized platforms and tools to support teacher development.

These findings collectively indicate that successful technology integration in teacher education programs requires a multi-faceted approach to institutional support. Institutions must not only provide adequate technical infrastructure but also develop comprehensive support systems that address pedagogical, technical, and professional development needs. The research suggests that effective institutional support frameworks should be flexible, responsive to changing technological demands, and aligned with educational objectives while focusing strongly on practical application and real-world relevance. This body of literature underscores the critical role of institutional support and infrastructure in facilitating successful technology integration in teacher education programs. Future research might productively explore how institutions can develop more resilient and adaptable support systems that can effectively respond to rapidly evolving technological landscapes while maintaining high standards of educational quality and effectiveness.

2.3. Professional development frameworks for educational technology implementation in higher education

The evolving landscape of educational technology necessitates professional development frameworks to support effective implementation in higher education settings. Recent research emphasizes the critical importance of structured approaches to technology-focused professional development, particularly in preparing educators for emerging pedagogical challenges in digital learning environments. Abuhassna and Alnawajha (2023) conducted a systematic literature review that revealed significant gaps in existing professional development models, specifically in addressing the diverse needs of educators implementing educational technology. Their research emphasizes the necessity of integrating traditional instructional design models with broader theoretical frameworks

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to enhance comprehensive learning design competencies. Professional development frameworks have evolved significantly in response to changing educational demands. Ryan et al. (2022) examined the impact of co-designed professional learning programs, finding that collaborative approaches significantly enhance teacher confidence and implementation success. Their research demonstrates that when educators participate actively in designing their professional development experiences, they develop greater ownership over pedagogical practices and show improved technology integration outcomes. This finding is particularly relevant for higher education institutions seeking to develop effective professional development strategies.

The role of mentorship in professional development frameworks has emerged as a crucial factor. Dignath (2021) examined various teacher competency profiles and discovered that an eight-hour professional development program led to notable improvements in educators' self-efficacy and confidence in applying new instructional strategies. The impact was particularly pronounced in those who already possessed advanced competence. These findings emphasize the necessity of tailored professional development initiatives that address educators' varying skill levels. Technology integration frameworks have also evolved to address specific implementation challenges. Ma et al. (2022) identified key elements contributing to successful online professional development, including TPACK self-assessment and peer interaction. Their research demonstrates that professional development frameworks must incorporate both technical skill development and pedagogical application to be effective. This perspective is reinforced by Kao et al. (2023), who emphasize the importance of stable scaffolding through artifact-, peer-, and teacher support in professional development programs.

Recent studies have also highlighted the significance of institutional context in professional development effectiveness. Wu et al. (2021) explored factors influencing the development of learning design competency in PSTs, emphasizing the need for systematic, competence-oriented training that is interdisciplinary and student-centered. Their research led to the development of an online teacher training platform that integrates visual learning design tools with learning analytics functions, demonstrating the potential of technology-enhanced professional development frameworks. The impact of professional development on teaching practice has received considerable attention. Wong and Hughes (2022) examined how social cognitive motivational traits shape learning design competency development, finding that these traits significantly predict key learning behaviors. Their findings suggest that professional development frameworks should integrate strategies aimed at strengthening educators' self-efficacy and task-value beliefs. This finding aligns with research by Dai et al. (2022), who explored the effectiveness of VR-supported teacher training, demonstrating that extended exposure to immersive training environments fosters stronger teaching competencies.

The importance of continuous assessment and adaptation in professional development frameworks is emphasized in recent literature. Tuan (2022) identified four key factors—knowledge, skills, attitudes, and teaching situations—as critical influences on the development of learning design competencies. This research suggests that professional development frameworks must address all these components to effectively support technology implementation in higher education settings. Similarly, Lin et al. (2023) identified six critical factors influencing academic performance in distance learning environments, emphasizing the need for comprehensive professional development approaches that address multiple dimensions of technology integration. Looking toward future developments, Castañeda and Yeoman (2023) explore how professional development frameworks can be enhanced using specialized tools and approaches. Their research with the ACAD toolkit demonstrates the potential for structured support systems to enhance educational designers' capabilities and foster more effective technology integration practices. This perspective is particularly valuable for institutions seeking to develop or refine their professional development frameworks. This body of research collectively suggests that effective professional development frameworks for

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educational technology implementation must be comprehensive, flexible, and responsive to educators' needs while maintaining a strong focus on practical application and measurable outcomes. Future research directions might productively explore how professional development frameworks can better adapt to rapidly evolving technological landscapes while ensuring sustainable and effective implementation practices in higher education settings.

3. Methodology

This study employed a comprehensive mixed-methods sequential explanatory design to examine critical and creative thinking capabilities in teacher education programs in Thailand. Conducted across multiple higher education institutions from January to December 2024, the research aimed to provide both breadth and depth in understanding the intricate dynamics of cognitive skill development in teacher preparation programs. This methodological approach was selected to ensure an exploration of the factors influencing these essential competencies.

3.1. Research Design

The investigation followed a two-phase mixed-methods approach, carefully structured to maximize data comprehensiveness and validity. The first phase encompassed quantitative data collection through meticulously designed surveys and assessments, establishing baseline measurements, and identifying broad patterns in critical and creative thinking capabilities. This was followed by a qualitative phase comprising in-depth interviews and focus group discussions, allowing for detailed exploration of underlying factors and contextual influences. To enhance the reliability of qualitative insights, the interview questions and discussion prompts were developed based on key themes emerging from the quantitative findings. The sequential nature of this design enabled each phase to inform and enhance the subsequent investigation, with quantitative findings guiding the development of qualitative inquiry protocols.

3.2. Participant Selection and Sampling Procedures

The study engaged 85 PSTs selected through a stratified random sampling process from accredited teacher education programs across Thailand. The stratification process considered institutional type, geographical location, and program specialization to ensure representative sampling. Sample size determination utilized G*Power analysis software, with parameters set at α = .05, power = .80, and medium effect size (d = 0.5), ensuring statistical validity while maintaining practical feasibility. Additionally, 11 faculty members were selected based on their direct involvement in pedagogical development and assessment. The qualitative phase involved 20 participants chosen through purposive sampling for in-depth interviews, with selection criteria including experience level, technological proficiency, and teaching context diversity. Four focus groups were conducted, each comprising 6-8 participants strategically selected to represent varied perspectives and experiences in teacher education.

3.3. Data Collection Instruments and Procedures

The quantitative phase employed three meticulously validated instruments. The Critical and Creative Thinking Assessment (CCTA) was developed through extensive pilot testing and expert review, measuring five core components through a 50-item assessment tool. Each component underwent reliability testing, yielding a composite Cronbach's alpha of 0.89. The Technology Readiness Survey (TRS) incorporated 35 items across five domains, with construct validity established through confirmatory factor analysis (CFA fit indices: CFI = 0.92, RMSEA = 0.058). The Faculty Perception Questionnaire (FPQ) comprised 40 items measuring instructional strategy effectiveness and implementation challenges, demonstrating high internal consistency (α = 0.87).

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Qualitative data collection procedures involved carefully structured protocols. The semi-structured interview guide was developed through a rigorous process, including (1) a comprehensive literature review on critical and creative thinking in teacher education, (2) expert consultation with three specialists in teacher education and educational technology, and (3) pilot testing with five PSTs from institutions not included in the main study to refine question clarity and structure. The guide covered five thematic areas: critical-creative thinking development, technology integration, teaching challenges, institutional support, and professional development needs. Content validation was conducted using the Item-Objective Congruence (IOC) method, with items scoring below 0.80 being revised. Semi-structured interviews followed a validated interview guide, incorporating open-ended questions and probing techniques to elicit detailed responses.

Focus group discussions utilized structured facilitation protocols to ensure balanced participation and comprehensive topic coverage. The focus group protocol maintained a similar content structure to the interview guide with additional prompts for group interaction. Sessions were conducted by a trained moderator with a note-taker documenting group dynamics, each lasting approximately 90 minutes. All sessions were audio-recorded and transcribed verbatim, with field notes capturing non-verbal cues and contextual information.

Additionally, classroom observations were conducted using standardized observation protocols to document teaching practices and technology implementation. The rubric incorporated rating scales and descriptive field notes. Two trained observers conducted independent pilot observations, achieving a Cohen's kappa coefficient of 0.84, ensuring strong inter-rater reliability. Each participant was observed twice in different teaching contexts, and post-observation interviews were conducted to clarify instructional choices and contextual influences.

3.4. Data Analysis Framework

The analysis framework incorporated both statistical and interpretative approaches. Quantitative data underwent preliminary screening for missing values and outliers using SPSS version 28.0. Descriptive statistics established baseline patterns, while inferential analyses examined relationships between variables. Multiple regression analyses investigated predictive relationships between technological readiness and cognitive development outcomes. T-tests compared implementation levels across different institutional contexts, while chi-square analyses examined categorical associations. Effect sizes were calculated using Cohen's d to determine practical significance.

Qualitative data analysis followed Braun and Clarke's systematic thematic analysis framework—initial coding utilized both inductive and deductive approaches, with codes developed through iterative reading of transcripts. Theme development involved clustering related codes and identifying patterns across data sets. Theme refinement underwent peer review and member checking to ensure interpretative validity. The integration of quantitative and qualitative findings employed a convergent parallel approach, where separate analyses were conducted before synthesis into comprehensive interpretations.

3.5. Quality Assurance and Validity Measures

The study employed quality assurance measures to ensure methodological soundness and research validity. Quality control procedures were implemented throughout the research process, including both preventive and evaluative measures to support scientific standards.

3.5.1. Instrument Validation and Reliability

All research instruments underwent extensive validation procedures before implementation. The Critical and Creative Thinking Assessment (CCTA) was subjected to content validation through an

expert panel review involving eight specialists in educational psychology and teacher education. Using a standardized evaluation matrix, the panel evaluated each item for content relevance, clarity, and construct alignment. Items achieving a Content Validity Index (CVI) below 0.80 were either revised or eliminated. The refined instrument underwent pilot testing with 45 PSTs from institutions not included in the main study, leading to further refinements in item wording and response options

The Technology Readiness Survey (TRS) and Faculty Perception Questionnaire (FPQ) followed similar validation protocols. Both instruments were pilot-tested and underwent factor analysis to confirm construct validity. The TRS demonstrated strong internal consistency across all five domains (Cronbach's α ranging from 0.85 to 0.92), while the FPQ showed reliability coefficients (α = 0.87 to 0.91) for its major subscales.

3.6. Data Collection Quality Control

To ensure consistency in data collection, all research assistants underwent intensive training in standardized administration procedures. The training program included theoretical instruction, practical demonstrations, and supervised practice sessions. Inter-rater reliability was established through parallel coding exercises, achieving Cohen's kappa coefficients exceeding 0.85 across all measurement domains. Interviewers and focus group facilitators received additional training in qualitative interviewing techniques, active listening, and neutral probing strategies for qualitative data collection.

For qualitative data collection, several quality control measures were implemented. Interview protocols were standardized through pilot testing and expert review. All interviews were conducted by researchers with extensive qualitative research experience, and regular debriefing sessions were held to maintain consistency in interviewing approaches. Focus group moderators received specialized training in group facilitation and probing techniques to ensure rich data collection while maintaining neutrality.

3.7. Data Analysis and Interpretation Validation

The analysis phase included several validation strategies. For quantitative data, statistical assumptions were tested before analysis, including checks for normality, homoscedasticity, and multicollinearity. Outlier analysis combined statistical methods (Mahalanobis distance) and contextual evaluation to examine data patterns while considering valid extreme cases.

Qualitative data analysis included validation through member checking and peer review. Interview transcripts were shared with participants to verify accuracy and meaning. Additionally, to further enhance data trustworthiness, method triangulation was employed by cross-referencing interview findings with survey results and observational data. The thematic analysis involved coding by multiple researchers who met to discuss and revise the coding framework. An external researcher with expertise in educational research methodology reviewed the analysis process and interpretations.

4. Results

4.1. Status of critical and creative thinking capabilities among PSTs in Thailand's next normal era

This section presents quantitative and qualitative data analysis examining critical and creative thinking capabilities in PSTs. The analysis combines data from 85 survey participants, in-depth interviews (n=20), and focus group discussions (n=4). The assessment of critical and creative thinking capabilities identified patterns across cognitive dimensions. The analysis examined five components using an assessment framework. Table 1 presents the statistical analysis of these components, including measures of central tendency, variability, and effect sizes.

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Table 1. Statistical analysis of critical and creative thinking components

Component	Mean Score (%)	SD	t-value	p-value	Effect Size (d)
Questioning Ability	78.5	8.24	4.82	<.001	0.76
Data Analysis	82.3	7.56	5.14	<.001	0.82
Creative Thinking	75.8	9.12	4.35	<.001	0.71
Critical Evaluation	73.2	8.95	4.08	<.001	0.68
Problem-Solving	76.9	8.73	4.56	<.001	0.74

Note: N=85, significance level α=.05

The quantitative results show variations in performance across thinking dimensions. Data analysis showed a mean score of 82.3% (SD = 7.56) with an effect size of d = 0.82. Data analysis performance correlated with participants' exposure to digital learning tools ($r = 0.72$, $p < .001$) and their engagement with online analytical platforms. Questioning ability showed the next highest scores (M = 78.5%, SD = 8.24, d = 0.76). The standard deviation suggests similar performance levels across participants. Multiple regression analysis indicated that questioning ability predicted teaching effectiveness in simulated classroom environments ($\beta = 0.64$, $p < .001$, $R^2 = 0.41$).

4.1.1. Qualitative Insights into Thinking Development

The qualitative analysis provided insights into the factors influencing critical and creative thinking development. Through thematic analysis of interview transcripts and focus group discussions, several key patterns emerged regarding the development of these cognitive capabilities. PSTs consistently reported that transitioning to hybrid learning environments enhanced their critical thinking development. As one participant explained: *"The hybrid learning environment forced us to become more independent in our analysis and decision-making. We couldn't rely on immediate feedback from instructors, which made us think more critically about our choices."*

The integration of digital tools and platforms significantly influenced creative thinking processes. Participants described how technology-enhanced learning environments provided new opportunities for creative expression and problem-solving. For instance, a focus group participant noted: *"Using digital collaboration tools opened up new ways of approaching problems. We could experiment with different solutions and get immediate feedback from peers, which helped develop our creative thinking skills."*

The convergence of quantitative and qualitative data reveals several significant patterns. 1) The statistical correlation between digital tool proficiency and critical thinking scores ($r = 0.72$, $p < .001$) aligns with qualitative reports of enhanced analytical capabilities through technology integration. 2) The lower scores in critical evaluation (M = 73.2%, SD = 8.95) correspond with interview data suggesting challenges in evaluating information from multiple digital sources.

Regression analysis indicated that engagement with project-based learning activities significantly predicted higher creative thinking scores ($\beta = 0.68$, $p < .001$, $R^2 = 0.46$). This quantitative finding was substantiated by qualitative data, where participants frequently cited project-based learning as a crucial factor in developing their creative problem-solving abilities. These integrated findings suggest that while PSTs have developed strong capabilities in certain areas of critical and creative thinking, specific aspects still require targeted development. The combination of quantitative and qualitative data provides a comprehensive understanding of both the status and the factors influencing these cognitive capabilities.

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4.2. Instructional strategies and pedagogical approaches for promoting critical and creative thinking capabilities in teacher education programs

This section presents an analysis of faculty perspectives regarding instructional strategies and pedagogical approaches used to promote critical and creative thinking capabilities in teacher education programs. The analysis combines quantitative data from faculty surveys (N=11) with qualitative insights from in-depth interviews, providing a comprehensive understanding of current teaching practices and their effectiveness.

4.2.1. Effectiveness and implementation of teaching strategies

The quantitative analysis revealed significant patterns in both the effectiveness and implementation of various teaching strategies (Table 2). Statistical analysis indicates substantial variations between perceived effectiveness and actual implementation levels across different pedagogical approaches.

Table 2. Analysis of Teaching Strategies Effectiveness and Implementation

Teaching Strategy	Effectiveness (M±SD)	Implementation (M±SD)	Correlation (r)
Project-based Learning	4.8±0.4	3.9±0.6	0.72
Digital Tools Integration	4.6±0.4	4.2±0.5	0.68
Collaborative Learning	4.5±0.5	3.8±0.6	0.65
Problem-based Learning	4.4±0.5	3.7±0.7	0.63
Inquiry-based Learning	4.3±0.6	3.5±0.7	0.61

The data presented in Table 2 demonstrates that project-based learning achieved the highest effectiveness rating (M = 4.8, SD = 0.4) among all strategies evaluated. However, a significant gap exists between its perceived effectiveness and actual implementation level (M = 3.9, SD = 0.6), as indicated by the gap analysis ($t(10) = 3.24$, $p < .01$). The strong correlation between project-based learning and improved student outcomes ($r = 0.72$) suggests its effectiveness in developing critical thinking capabilities.

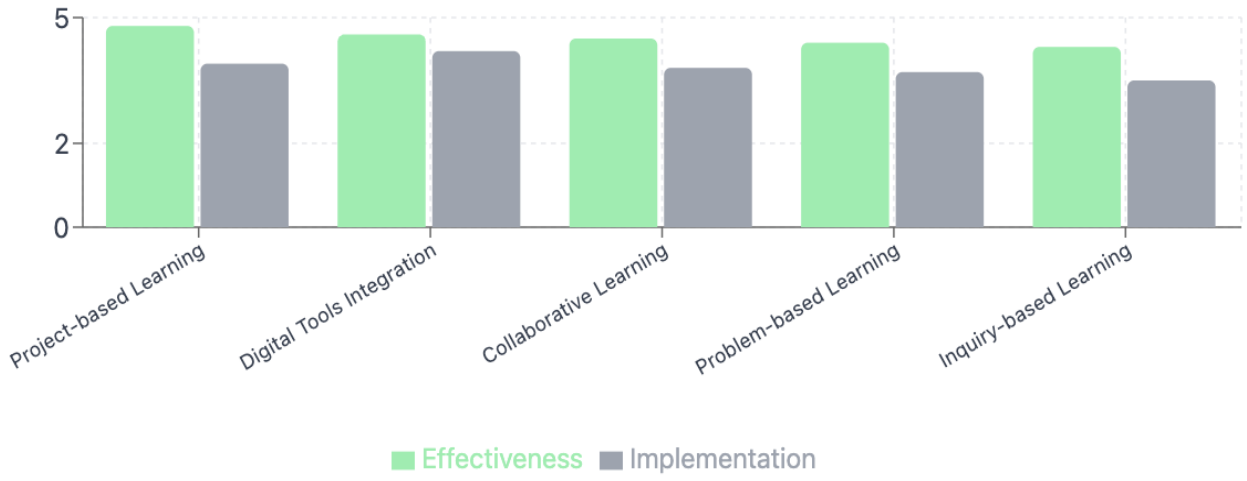

Figure 1. Comparison of Teaching Strategies Effectiveness and Implementation Levels

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As illustrated in Figure 1, digital tools integration demonstrated both high effectiveness (M = 4.6, SD = 0.4) and the highest implementation level (M = 4.2, SD = 0.5) compared to other strategies. This successful integration reflects faculty members' adaptation to technology-enhanced teaching methods, supported by a strong correlation between implementation and effectiveness (r = 0.68).

4.2.3. Integration of pedagogical approaches

Qualitative analysis of faculty interviews revealed several key factors contributing to successfully implementing these teaching strategies. Faculty members emphasized the importance of integrating multiple approaches to create comprehensive learning experiences. As one participant noted: "The combination of project-based learning with digital tools has created powerful opportunities for developing both critical and creative thinking skills." The integration of technology with traditional pedagogical approaches emerged as a crucial factor. Faculty members reported that successful implementation required careful consideration of both technological capabilities and fundamental teaching principles. Another participant explained: *"While digital tools enhance our teaching capabilities, we focus on developing students' cognitive abilities through structured learning experiences that combine traditional and innovative approaches."*

4.2.4. Implementation challenges and success factors

The study identified several critical challenges affecting the implementation of these teaching strategies:

Time constraints emerged as the primary barrier, with 82% of faculty members reporting insufficient preparation time for implementing innovative teaching methods. Technical infrastructure limitations also affected the implementation of digital learning strategies, particularly in remote learning contexts. Additionally, varying levels of student readiness necessitated additional support and scaffolding. However, analysis of successful cases revealed key factors contributing to effective implementation. Strong institutional support through resource allocation and policy alignment proved crucial. Regular professional development opportunities focused on pedagogical innovation enhanced faculty capabilities. Additionally, collaborative planning and the exchange of best practices supported the effective adoption of new teaching methodologies. These findings suggest that while faculty members recognize the value of various teaching strategies for promoting critical and creative thinking, successful implementation requires careful attention to both pedagogical design and institutional support systems. The data indicates that a balanced approach, combining traditional teaching methods with innovative digital tools, offers the most promising path forward in teacher education programs.

4.3. Analysis of technological readiness and educational management approaches in teacher education programs during the next normal era

This section presents comprehensive findings on technological readiness and educational management approaches in Thailand's higher education institutions. The analysis integrates quantitative data collected from survey responses of 85 PSTs with qualitative insights gathered through four focus group discussions and twenty in-depth interviews.

4.3.1. Technology integration and readiness assessment

The quantitative analysis revealed complex patterns of technological readiness and implementation across different domains of educational technology. Table 3 presents a detailed analysis of these findings, including readiness levels, usage frequencies, confidence levels, and implementation success rates across various technological platforms and tools.

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Table 3. Technological readiness assessment of PSTs (N=85)

Technology Domain	Readiness Level (M±SD)	Usage Frequency (%)	Confidence Level (M±SD)	Implementation Success (%)
Learning Management Systems	4.2±0.6	87.5	3.9±0.7	82.3
Digital Content Creation	3.8±0.8	75.2	3.5±0.9	68.4
Online Assessment Tools	3.9±0.7	79.8	3.7±0.8	74.6
Collaborative Platforms	4.1±0.5	84.3	4.0±0.6	80.1
Educational Applications	3.7±0.9	72.4	3.4±1.0	65.8

Note: Readiness and confidence levels measured on 5-point Likert scale (1 = lowest, 5 = highest). Usage Frequency indicates percentage of regular users. Implementation success shows successful application in teaching practice.

The data demonstrates significant variations in technological readiness and implementation success across different domains. Learning management systems emerged as the area of highest competency, with PSTs demonstrating strong readiness levels (M = 4.2, SD = 0.6) and substantial implementation success rates (82.3%). This high-performance correlate significantly with the frequent usage patterns observed (87.5%) and notably high confidence levels (M = 3.9, SD = 0.7) among participants.

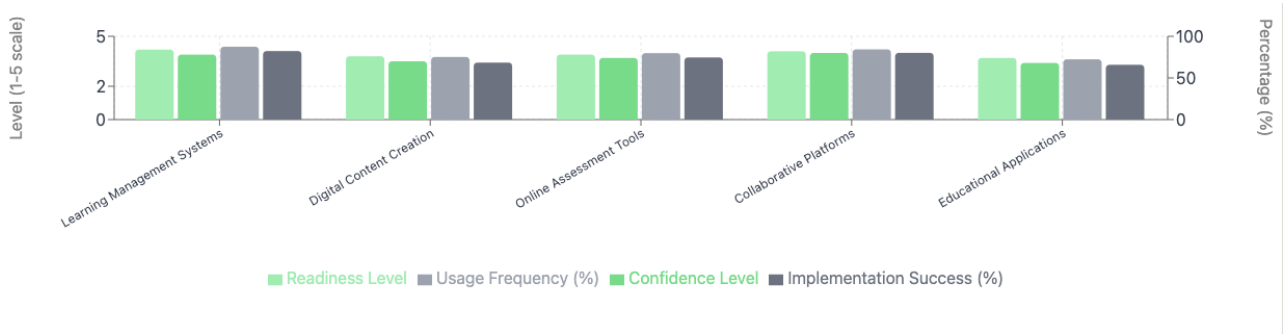

Figure 2. Technology Domain Assessment Metrics Comparison

Statistical analysis reveals a strong positive correlation between readiness levels and implementation success ($r = 0.78$, $p < .001$) across all technology domains. Collaborative platforms showed the second-highest readiness levels (M = 4.1, SD = 0.5), with implementation success rates of 80.1% and usage frequency of 84.3%.

4.3.2. Infrastructure and resource analysis

Through qualitative analysis, three main themes emerged regarding technological infrastructure and resources: 1) The availability and quality of technological resources varied significantly between urban and rural settings. Urban-based PSTs reported consistent access to high-speed internet (82% of respondents) and necessary devices (78%), while rural placements showed lower accessibility rates (55% and 48% respectively). 2) Institutional support systems demonstrated varying levels of effectiveness. PSTs in institutions with established technical support reported higher confidence levels in technology integration (M = 4.3, SD = 0.5) compared to those without structured support (M

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= 3.1, SD = 0.8). and 3) Resource allocation patterns influenced implementation success. Institutions providing dedicated technical resources showed higher implementation success rates (84.5%) compared to those with limited resource allocation (61.2%).

4.3.3. Professional development and skills assessment

Analysis of professional development needs revealed specific skill gaps across various technological domains. Digital content creation emerged as the primary area requiring enhancement, with 72% of participants indicating the need for additional training. Online assessment design followed, with 68% expressing the need for skill development. Statistical analysis showed that participants who received structured training demonstrated significantly higher implementation success rates ($t(83) = 4.26$, $p < .001$, $d = 0.82$) compared to those without formal training programs.

4.4.4. Technology integration patterns

The study identified distinctive patterns in technology integration across different teaching contexts. Quantitative data revealed that synchronous teaching tools had the highest adoption rate (85.3%), followed by learning management systems (82.3%) and assessment tools (74.6%). Cross-tabulation analysis demonstrated significant associations between successful technology integration and several key institutional factors. Regular access to technical support showed a strong relationship with successful implementation ($\chi^2 = 15.42$, $p < .001$), indicating that consistent technical assistance plays a crucial role in technology adoption. Similarly, the presence of structured professional development programs demonstrated a significant association with integration success ($\chi^2 = 12.86$, $p < .001$), highlighting the importance of systematic training approaches. The quality of institutional infrastructure also emerged as a significant factor ($\chi^2 = 14.23$, $p < .001$), suggesting that technological infrastructure forms a critical foundation for successful technology integration in educational settings. These statistical relationships underscore the interconnected nature of support systems, professional development, and infrastructure in facilitating effective technology integration.

The results demonstrate complex interrelationships between technological readiness, infrastructure support, and successful implementation in teacher education programs. These findings provide a foundation for understanding the current state of technological integration in teacher education.

5. Discussion

5.1. Critical and creative thinking capabilities in the next normal era

The findings highlight key trends in the enhancement of critical and creative thinking capabilities in teacher education. Data analysis emerged as a fundamental skill contributing to cognitive development, reinforcing the role of digital tools in fostering analytical reasoning among pre-service teachers. This aligns with research emphasizing the necessity of data literacy for educators in digital learning environments. These findings align with recent research by Huang and Sang (2023), who identified the dual dimensions of logical and value-oriented competencies in teacher education. However, our results extend their framework by demonstrating stronger correlations between technological integration and cognitive development than previously reported.

Babenko (2020) also emphasizes that digital competency development is an interdependent process requiring both evaluation and imaginative idea generation, further supporting our findings on the integration of critical and creative thinking. While Silva et al. (2022) suggested that conventional curricula alone were insufficient for developing competencies, our research provides empirical evidence for the effectiveness of integrated digital approaches, particularly in enhancing analytical capabilities. The lower performance in critical evaluation contrasts with Wong et al.'s (2021) findings, possibly due to differences in institutional support structures and implementation

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strategies. Our findings carry significant implications for teacher education programs in the post-pandemic era. The study also reinforces Bosch's (2022) assertion that digital competency development is heavily influenced by institutional support and peer collaboration, suggesting that structured mentoring programs could enhance pre-service teachers' ability to critically evaluate digital resources.

The strong correlation between project-based learning engagement and creative thinking scores suggests the need for more structured experiential learning opportunities. Future research should explore the long-term sustainability of these enhanced cognitive capabilities and investigate potential interventions for improving critical evaluation skills, particularly in digital environments. As Olney et al. (2023) note, competency frameworks in digital education should include instructional design training and stakeholder management, further highlighting the need for interdisciplinary approaches to competency development. The research also raises questions about the transferability of these capabilities across different educational contexts and the role of cultural factors in shaping cognitive development patterns.

5.2. Instructional strategies and pedagogical approaches for critical and creative thinking development

The analysis of instructional strategies reveals compelling patterns in the effectiveness and implementation of various pedagogical approaches. Project-based learning demonstrated the highest effectiveness rating yet faced significant implementation challenges, aligning with Ryan et al. (2022), who found that institutional constraints often limit the scalability of experiential learning methods in teacher education. This implementation gap highlights a critical disconnect between pedagogical ideals and practical realities in teacher education programs. The strong correlation between project-based learning and student outcomes underscores its potential as a transformative teaching strategy, particularly when integrated with digital tools.

These findings both support and extend previous research in the field. Olney et al. (2023)'s emphasis on learner-centered design frameworks aligns with our observations regarding the effectiveness of integrated pedagogical approaches. Additionally, McBride et al. (2023) highlight that playful learning experiences and game-based strategies significantly enhance digital competency, reinforcing the importance of interactive instructional methods. However, our study reveals more substantial implementation challenges than those reported by Ryan et al. (2022), particularly in resource-constrained environments. The high effectiveness of digital tools integration supports McBride et al.'s (2023) findings on the importance of playful learning experiences, while also highlighting the role of institutional support in successful implementation. Notably, our research identifies specific barriers not previously emphasized in the literature, such as time constraints of faculty members and varying levels of student readiness. These barriers reflect findings by Silva et al. (2022), who identified that digital competency development often requires long-term engagement beyond conventional coursework.

The implications of these findings extend beyond immediate pedagogical practices to broader considerations of teacher education program design. The significant association between institutional support and implementation success suggests the need for systematic changes in program structure and resource allocation. Future research should explore the development of scalable models for implementing effective teaching strategies, particularly in contexts with limited resources. Additionally, investigation into the long-term impact of these pedagogical approaches on teacher development and student outcomes would provide valuable insights for program design and policy development.

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5.3. Technological readiness and educational management approaches

The comprehensive analysis of technological readiness and educational management approaches reveals nuanced patterns in technology integration within teacher education programs. Learning Management Systems emerged as the area of highest competency with implementation success, indicating successful adaptation to digital teaching environments. The strong correlation between readiness levels and implementation success across all technology domains suggests that systematic technological preparation significantly influences teaching effectiveness. These findings both complement and challenge existing research. While Boer and Asino (2022) identified infrastructure limitations as primary barriers, our study reveals a more complex interplay between technical capability and institutional support. The significant disparity in access between urban and rural settings extends beyond previous findings by Núñez-Canal et al. (2022), suggesting more pronounced geographical inequities in our context. The positive impact of structured support systems on technology integration confidence aligns with Wu et al.'s (2021) findings but demonstrates stronger effect sizes in our study. The research highlights critical areas for future development in teacher education programs. The identified skill gaps in digital content creation and online assessment design suggest specific areas for targeted intervention. Future research should investigate the effectiveness of different professional development models in addressing these gaps, particularly in resource-constrained environments. Additionally, the strong associations between institutional factors and successful technology integration indicate the need for more comprehensive institutional support frameworks that can adapt to evolving technological demands while maintaining educational quality and effectiveness.

6. Research Limitations

This study, while comprehensive in its approach, encountered several methodological and practical limitations that warrant consideration. The geographic scope, focused primarily on Thailand's higher education institutions, may limit the generalizability of findings to other cultural and educational contexts. Additionally, the timing of data collection during the ongoing digital transformation period means that some findings may reflect transitional rather than stable patterns of technology integration and pedagogical adaptation. The sample size of 85 PSTs and 11 faculty members, while statistically sufficient for the study's purposes, represents a fraction of the total population of teacher education programs in Thailand. Furthermore, the self-reported nature of some data collection instruments may have introduced response bias, particularly regarding technological competency and implementation success rates.

6.1. Research Implications and Practical Applications

The findings from this study have significant implications for various stakeholders in teacher education. For teacher education institutions, the results provide evidence-based guidance for developing comprehensive programs that effectively integrate critical and creative thinking development with technological competency. The strong correlation between structured support systems and implementation success suggests that institutions should prioritize establishing technical infrastructure and ongoing professional development programs. The identified disparities between urban and rural settings highlight the need for targeted interventions to ensure equitable access to technological resources.

For faculty members and instructional designers, this research offers practical insights into effective pedagogical approaches. The high effectiveness rating of project-based learning paired with its implementation challenges suggests the need for more structured support systems and resource allocation. The success of digital tools integration provides a model for balancing technological innovation with pedagogical effectiveness.

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For policymakers, the findings underscore the importance of developing comprehensive frameworks that address both immediate technical needs and long-term professional development requirements. The significant gap between perceived effectiveness and actual implementation levels across various teaching strategies calls for policy interventions that support sustained, systematic changes in teacher education programs.

6.2. Recommendations for Future Research

Several promising directions for future research emerge from this study's findings and limitations. First, longitudinal studies tracking the development and application of critical and creative thinking capabilities throughout PSTs' transition to professional practice would provide valuable insights into the long-term effectiveness of different pedagogical approaches. Such research could help identify which interventions have sustainable impact beyond the initial training period. Second, comparative studies examining the effectiveness of various professional development models across different cultural and institutional contexts help address the generalizability limitations of the current study. This research would be particularly valuable in understanding how different support systems and implementation strategies might be adapted for various educational settings. Third, investigation into the relationship between technological integration patterns and student learning outcomes would provide crucial evidence for the effectiveness of different pedagogical approaches. This research should particularly focus on how various combinations of traditional and innovative teaching methods affect the development of higher-order thinking skills among both PSTs and their future students. Finally, research exploring the development of more sophisticated assessment tools for measuring critical and creative thinking capabilities in digital learning environments would address current measurement limitations. Such tools should incorporate both quantitative and qualitative measures to provide a more comprehensive understanding of cognitive skill development in technology-enhanced learning environments. These recommendations for future research align with the identified gaps in current literature while building upon the methodological foundations established in this study. By pursuing these research directions, the field can continue to develop more effective approaches to teacher preparation in response to evolving educational demands.

7. Conclusion

This study provides important perspectives on the enhancement of critical and creative thinking capabilities in teacher preparation programs in Thailand. The findings reveal complex patterns in cognitive skill development, with data analysis emerging as the strongest capability ($M = 82.3\%$, $SD = 7.56$) and demonstrating a strong correlation with digital tool proficiency ($r = 0.72$, $p < .001$). The implementation of project-based learning showed the highest effectiveness rating ($M = 4.8$, $SD = 0.4$), although significant gaps between perceived effectiveness and actual implementation levels highlight ongoing challenges in teacher education programs. The study also identified substantial disparities in technological readiness between urban and rural settings, with access rates varying from 82% to 55% respectively. These findings contribute to our understanding of how institutional support, pedagogical approaches, and technological integration influence the development of critical and creative thinking capabilities in teacher education. The research concludes that successful development of these essential cognitive skills requires a balanced approach that combines structured support systems, innovative pedagogical strategies, and technological infrastructure, while addressing the specific needs and constraints of different educational contexts.

Declarations

Author Contributions. All authors contributed to the study's planning, design of the data collection instrument, and data collection and analysis. The first author led the writing process with assistance from other authors. All the authors read and approved the final manuscript.

https://doi.org/10.22521/edupij.2025.15.103 Published online by Universitepark Press

Conflicts of Interest. The authors declare no conflict of interest.
Funding. Not applicable.
Ethical Statement. The study received approval from the Center for Ethics in Human Research Committee, Khon Kaen University (approval HE673105). Informed consent was obtained from all participants, with privacy and data storage protocols strictly followed.
Data Availability Statement. The data supporting this study's findings are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.
Acknowledgments. The authors would like to acknowledge the contributions of the pre-service teachers and lecturers who participated in this research.

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