

Development of a Microlearning-integrated Blended Learning Model Delivered via an Online Platform to Enhance Pre-service Teachers' Digital Skills

Panuwat Srichailard and Uraiwan Srichailard *

Department of Computer Education, Faculty of Science and Technology, Nakhon Pathom Rajabhat University, Nakhon Pathom, Thailand
Email: panuwat@webmail.npru.ac.th (P.S.); uraiwannat@webmail.npru.ac.th (U.S.)

*Corresponding author

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Abstract—Persistent challenges in teachers' digital readiness continue to highlight the need for practical digital skills required for effective instructional practice. This study aimed to (1) develop a microlearning-integrated blended learning model delivered via an online platform, (2) evaluate its instructional efficiency, and (3) examine its effectiveness in enhancing pre-service teachers' digital skills. A research and development approach was employed using a one-group pretest–posttest design with 268 pre-service teachers over six weeks. Instruction was implemented in a 50:50 online–offline format. Data were analyzed using descriptive statistics and paired t-tests to assess changes in digital skills across six performance-based domains. The results showed that the developed MB Learning Model achieved an instructional efficiency of $E1/E2 = 90.88/86.76$, exceeding the established 80/80 benchmark. Significant improvements were observed across all six digital skill domains ($p < 0.001$), with the overall digital skill score increasing from $M = 39.52$ to $M = 54.53$. These findings indicate substantial gains in both declarative knowledge and performance-based competencies. The findings suggest that the structured integration of microlearning within a blended learning environment delivered via an online platform is associated with improvements in digital skill development. However, due to the absence of a control group, the results should be interpreted with caution, as causal relationships cannot be definitively established. Despite this limitation, the model demonstrates practical potential as a structured instructional framework for supporting digital skill development in teacher education contexts.

Keywords—microlearning, blended learning, online learning platform, pre-service teachers, digital skills

I. INTRODUCTION

Education systems worldwide continue to face challenges in preparing teachers with practical digital competencies required for technology-enhanced instruction and sustainable professional practice. Increasing expectations for authentic digital pedagogy, online communication, digital assessment, and technology-supported learning management have intensified the need for pre-service teachers to develop both conceptual understanding and applied digital skills. Previous studies have reported persistent gaps in teachers' readiness to effectively integrate digital technologies into instructional practice, particularly in digital media production, online instructional management, and technology-supported assessment. Organizations and educational institutions have therefore increasingly emphasized the importance of strengthening teachers' digital readiness and professional upskilling to support evolving educational environments. Promwong *et al.* [1] recommended that schools organize professional-development workshops led by experts in online

media to enhance teachers' preparedness. Their findings further indicated that teachers sought to develop competencies in applying digital technologies, using media effectively, designing lessons for both online and offline contexts, creating instructional media systematically, and employing technology-supported assessment methods. Beyond the post-COVID-19 educational context, the development of practical digital competencies among pre-service teachers remains an ongoing challenge in teacher education. Increasing expectations for technology-enhanced teaching, authentic digital instructional practices, and sustainable digital skill development continue to require instructional approaches that effectively integrate digital learning processes with practical performance-based experiences.

International evidence points to similar capacity gaps. For example, Alonso-Garcia *et al.* [2] assessed teachers' digital skills from the perspective of university students at the University of Granada, reported that most students perceived teachers' digital skills as insufficient for fully delivering course content. In a related study, Arnold and Subaveerapandian [3] found that teachers' digital skills ranged from moderate to high overall, while emphasizing the need to ensure readiness across all areas in a comprehensive manner.

Developing teachers' digital skills is essential. Digital skills refer to the knowledge and ability to effectively use digital technologies, including tools such as computers, mobile devices, software applications, and online media, to support communication, task performance, and collaboration, as well as to enhance organizational efficiency. Based on this definition, the researcher reviewed prior studies on teachers' digital competence and synthesized key components aligned with the study context. The essential digital skills identified include digital-media authoring, internet literacy, educational use of social media, digital-media production, the use of tools for student measurement and evaluation [4], technology-enhanced instructional management [5], and ethical and responsible media use [6]. These skills represent core competencies required for effective teaching. Therefore, instructional design should focus on engaging learners in ways that support meaningful understanding and high-quality performance in practice.

Nakhon Pathom Rajabhat University is a well-recognized institution for preparing professional teachers, offering instruction across 17 teacher education programs that cultivate diverse, program-specific competencies. In addition

to disciplinary coursework, pre-service teachers are required to complete general-education courses that build foundational skills for future employment. Under the 2023 curriculum, these include the course “21st-Century Skills for Life and Career”, which integrates theoretical study with practical training to enable students to use various computer programs for instructional purposes; selected topics in digital skills are incorporated as part of the course content. However, evidence from instructional outcomes indicates that students’ baseline digital skills for the teaching profession remains insufficient for performing at a high level during the school practicum, which can negatively affect both academic programs and the university. This concern is heightened by schools’ growing reliance on digital skills in teaching and in broader school operations. Interviews with mentor teachers further revealed that schools generally expect pre-service teachers to assist staff and to transfer up-to-date knowledge and practices at least to some extent, given that these students are members of a younger generation and are enrolled in continuously updated curricula designed to produce high-quality graduates. In light of the aforementioned challenges in teachers’ technology use, there is a need to strengthen teachers’ readiness and capacity in digital skills. As a teacher-preparation institution, the university should therefore prioritize, recognize, and cultivate digital skills among prospective teacher graduates so that they become capable practitioner-graduates who can apply their expertise to teaching and contribute to the development of educational products and organizational improvement. To develop such competencies in practice, appropriate content delivery and learning designs tailored to the target learner group are essential to achieving effective learning.

In contemporary instruction, new delivery formats have emerged to better align with learner needs and instructional contexts. Microlearning is one such approach that presents content in small, self-contained units, enabling learners to process information efficiently and connect it to broader concepts. Its concise format helps maintain attention and supports immediate understanding and application [7]. In addition to its effectiveness during instruction, microlearning also functions as a structured follow-up approach that supports retention and knowledge transfer. Evidence from Amarit and Longpradit [8] indicates that microlearning-based follow-up activities, incorporating brief tasks and guided check-ins, lead to significant improvements in learning outcomes and higher acceptance compared to conventional approaches. These findings support the integration of microlearning within blended learning designs, aligning with the present study’s emphasis on developing practical and sustainable digital skills among pre-service teachers.

Another important approach is blended learning. Sunatoe *et al.* [9] defined it as an instructional mode that integrates face-to-face classroom learning with technology-mediated learning, combining the strengths of both approaches. Similarly, Thungkanai [10] described blended learning as both an instructional model and a training strategy suited to the modern information society, enabling flexible learning through the integration of in-person and online environments.

Blended learning supports diverse knowledge construction, allowing learners to study without constraints of time and

place, while promoting interaction, communication, and the development of learning communities. It is widely adopted in higher education and has been shown to be effective in various contexts. However, effective implementation requires careful design of delivery channels and instructional strategies to sustain learner engagement.

A widely adopted instructional channel for higher education, suited to its learner population, is the online learning platform. This refers to an online service system that enables learners, instructors, and education-related units to leverage data, tools, and resources to support teaching and learning. Advances in technology have extended learning beyond traditional classrooms by employing digital tools to manage and enhance instruction, while also encouraging learners to pursue self-directed study through digital media and social networks. Such platforms promote equity of access by allowing learners to study and review materials whenever needed. In light of the foregoing principles and challenges, it is evident that teachers’ digital skills are of critical importance.

As a teacher preparation institution, it is essential to equip students with the readiness required for the school practicum and eventual professional practice. It is also expected that pre-service teachers will be able to transfer digital skills to in-service teachers and school staff. Accordingly, the researcher proposes the development of a microlearning-integrated blended learning model delivered via an online platform to enhance pre-service teachers’ digital skills so that they are prepared, knowledgeable, and skilled for the digital era and can generate benefits for themselves and their organizations. Research Objectives: To develop a microlearning integrated blended learning model delivered via an online learning platform to enhance pre-service teachers’ digital skills. To determine the instructional efficiency of the proposed model. To assess pre-service teachers’ digital skill levels after learning with the developed model.

II. LITERATURE REVIEW

A. Instructional Model

An instructional model is a systematic structure and patterned design for organizing teaching and learning. It is grounded in accepted philosophies, theories, principles, and concepts, and is operationalized as sequenced steps, processes, and teaching techniques to achieve learning objectives efficiently [11–18]. From a systems perspective, an instructional model specifies core components, objectives, content, methods, media, and assessment—and aligns them coherently with the learner and course context. From a learner-centered perspective, some scholars emphasize learners’ processes of encoding, processing, and memory as the organizing core [19], enabling activity designs that better accommodate the nature of learning. In terms of developmental methodology, the literature recommends designing and developing instructional models via research and development using the ADDIE framework to ensure systematicity and quality assurance [20]. In sum, an instructional model is a systemically patterned plan for instruction that specifies and harmonizes objectives, content, teaching methods, media/platforms, and assessment, all

grounded in theory and empirical evidence, to drive desired learning outcomes effectively and verifiably within the learner/course context.

B. Microlearning

Microlearning is an instructional approach that focuses on delivering content in small, well-defined units, with the aim of enabling learners to access and comprehend information efficiently within a short period of time. This approach has emerged in response to the constraints of time and the evolving learning behaviors of individuals in the digital era, who increasingly prefer flexible and on-demand learning experiences [21]. Scholars have defined microlearning as the design of learning experiences composed of concise content units that target specific learning objectives and can be completed within a few minutes. Such learning is typically delivered through digital media, including short videos, quizzes, and multimedia materials, which enhance learners' comprehension and retention [22]. From a theoretical perspective, microlearning is closely associated with the concept of cognitive load reduction. By segmenting content into smaller units, it facilitates more efficient information processing and supports segmented learning, which contributes to improved long-term retention [23]. Moreover, microlearning is recognized as an approach that supports flexible learning and self-directed learning. Learners are able to select and engage with specific content based on their individual needs and convenience, thereby promoting lifelong learning [24].

In summary, microlearning can be defined as “an instructional approach that delivers content in small units, requires a short duration of engagement, focuses on specific learning objectives, and supports flexible learning through digital media”. This definition reflects both the structural characteristics and the learning processes associated with microlearning in the digital age.

C. Blended Learning

Blended learning is the integration of face-to-face instruction with technology-mediated or online learning, combining the strengths of each modality in the design of learning activities to achieve intended outcomes [25]. The proportion of modalities may be adjusted to fit the context—for example, online: classroom at 70:30 or 50:50—while emphasizing interaction, learner participation, and the purposeful use of ICT to cultivate learning communities both inside and beyond the classroom [26]. From the literature review the researcher synthesized a blended learning model comprising the following steps: (1) Define Objectives & Plan: Specify clear learning objectives and targets; design learning activities that coherently connect online and offline components; (2) Develop Materials and Technology: Prepare appropriate materials (e.g., videos, online lessons, hands-on activities) and select technologies that support interactive learning; (3) Blended Learning Implementation: Conduct integrated activities across classroom (offline) and online platforms, emphasizing active learning and collaborative learning; (4) Monitor and Assess: Employ diverse assessment tools (e.g., quizzes, group projects, self-assessment) and provide timely feedback to reinforce learning progress; and (5) Reflect & Improve: Analyze learning outcomes using

data and stakeholder feedback, and refine content and processes to enhance instructional effectiveness.

D. Online Learning Platform

An online learning platform refers to a digital system that serves as a central hub for managing content, learning activities, communication, and monitoring learners' progress [27, 28]. Such platforms play an important role in supporting self-directed learning, learner engagement, and instructional management in both online and blended learning formats. In the context of microlearning-integrated blended learning, the online platform functions as a primary tool for implementing instructional design in practice by supporting the organization of microlearning units, assignment submission, feedback provision, and communication between instructors and learners. Accordingly, this study adopts the concept of online learning platforms as a framework for describing the structure and operational processes of the system used to support instructional implementation.

Online learning platforms play a crucial role in supporting flexible and continuous learning environments. Beyond providing access to instructional content, effective platforms enable a range of pedagogical functions, including content delivery, assignment management, feedback provision, and progress tracking.

These functionalities allow instructors to design and organize learning materials systematically, monitor learner performance, and provide timely feedback. At the same time, learners can access learning resources at their own pace, complete tasks, and review feedback to improve their performance.

In the context of this study, the online platform was used not only as a content delivery tool but as an integrated learning environment that supports microlearning activities, facilitates interaction, and enables iterative feedback. This integration enhances learner engagement and supports self-directed learning, which are essential for developing digital competencies.

E. Digital Skills in Teacher Education

Teachers' digital skills constitute a key component of instructional practice in 21st-century educational contexts. Scholars have defined teachers' digital skills in a comprehensive manner, encompassing the effective, safe, and ethical use of technology to support learning, assessment, and continuous professional development [29, 30]. This perspective reflects that teachers' digital skills are not limited to technical competencies alone, but also include the ability to design and manage technology-enhanced learning in ways that are appropriate to learners' contexts. Redecker [31] proposed the Digital Skills Framework for Educators, which consists of six main dimensions, including professional engagement, digital resources, teaching and learning, assessment, empowering learners, and facilitating learners' digital skills. This framework has been widely applied in teacher education research as a guideline for designing learning activities and developing teachers in alignment with digital learning contexts. A review of the literature indicates that teachers' digital skills should encompass the appropriate selection of digital resources, the application of technology in instruction and assessment, communication and collaboration

through digital tools, as well as consideration of digital ethics and safety [32, 33].

Accordingly, in the present study, the concept and framework of teachers' digital skills were adopted as the

conceptual framework for designing learning activities and the structure of the platform, based on the researcher's synthesis, as presented in Table 1.

Table 1. Digital skills framework synthesis

Authors	Skill 1	Skill 2	Skill 3	Skill 4	Skill 5	Skill 6
Chawwiwat [34]	Internet literacy and use	Computer Operation Skills	Online Collaborative Working Skills	Safe Digital Technology Usage Skills	Digital Instructional Media Creation Skills	-
Donpila [35]	Educational Use of Social Media Skills	Digital Security and Cyber Safety Skills	Digital Instructional Media Creation Skills	-	-	-
Pablos <i>et al.</i> [4]	Digital Assessment and Evaluation Tool Utilization Skills	-	-	-	-	-
Demissie <i>et al.</i> [5]	Technology-Enhanced Instructional Management Skills	Web-Based Technology Utilization for Learning Skills	-	-	-	-
Sirisak and Traiwichitkhun [6]	Fundamental Knowledge of Digital Media and Technology	Digital Media and Technology Application Skills	Digital Media and Technology Selection Skills	Digital Media and Technology Production Skills	Ethical and Responsible Use of Digital Media Skills	-
Researcher	Digital media production for instructional purposes	Internet literacy and use	Educational use of social media	Use of tools for student measurement and assessment	Technology enhanced instructional management	Ethical and responsible media use

In addition to the conceptual foundations of microlearning, blended learning, and online learning platforms, this study is grounded in established learning theories to strengthen its theoretical framework.

First, Cognitive Load Theory explains how segmenting content into short microlearning units reduces extraneous cognitive load and facilitates efficient information processing. By presenting content in concise, structured segments, learners can better manage cognitive resources and retain essential information.

Second, Multimedia Learning Theory supports the design of instructional materials that integrate visual, auditory, and textual elements. the use of videos, demonstrations, and interactive media within the platform aligns with dual-channel processing principles, enhancing comprehension and retention.

third, Self-Regulated Learning Theory underpins the learner-centered nature of the model. The online platform enables learners to control the pace, sequence, and repetition of learning activities, thereby promoting autonomy, reflection, and continuous improvement.

Together, these theoretical perspectives provide a coherent foundation for the MB Learning Model, explaining how the integration of microlearning, blended learning, and platform-based instruction supports both knowledge acquisition and performance-based digital skill development.

III. MATERIALS AND METHODS

A. Participants

The sample comprised 268 undergraduate pre-service teachers at Nakhon Pathom Rajabhat University with student IDs for Academic Year 2023 (B.E. 2566). Participants were selected using a stage multistage cluster random sampling sequentially at the levels of faculty, academic program, and classroom, with a sample proportion of no less than 30% of the total population. All 268 participants received a full research briefing and provided informed, voluntary consent. Personally identifiable information was not collected; data

were anonymized and used solely for research purposes. The study received ethical approval from the Human Research Ethics Committee, Nakhon Pathom Rajabhat University (Approval No. 026/2567, dated 1 September 2024).

B. Research Design

This study employed a one-group pretest–posttest design to examine the effects of the MB Learning Model on students' digital skills. Participants completed a pretest prior to the intervention and a posttest after completing the instructional program.

C. Research Instruments and Quality

In this study, the development of research instruments was organized into three phases as follows.

1) Phase 1: Synthesis of the instructional model

The research needs were analyzed within the proposed framework to derive an initial conceptual model. Based on a review of the problem context, relevant documents, and prior studies, the researcher formulated preliminary concepts to guide the design and development of the R&D process. Upon completion of the model synthesis as presented in Table 2, the materials were submitted to subject matter experts for review. The researcher distributed the detailed synthesis document and an evaluation form to the experts. A purposive sample of 10 experts was selected, comprising six in computer science and instructional systems, two in information systems, and two in educational technology. All experts taught in computer education or educational technology programs, held doctoral degrees, and had at least three years of professional experience. Using a five-point rating scale, the experts' evaluations indicated that the synthesized instructional model was highly appropriate ($M = 4.91$, $SD = 0.29$) as presented in Table 3.

2) Phase 2: Development and quality assurance

Following synthesis and expert validation of the instructional model, the system was developed in accordance with the ADDIE process, as detailed below.

Table 2. The integration of microlearning and blended learning process concepts via an online learning platform

Results of the Synthesis of the Microlearning Model (Microlearning)	Results of the Synthesis of the Blended Learning Model (Blended Learning)	Microlearning and Blended Learning
Learning content is summarized into concise units, with each topic designed to be completed within approximately 3–5 min.	Defining learning objectives and planning.	Defining learning objectives.
Learning objectives are clearly defined.	Developing instructional materials and technology.	Designing microlearning and blended learning content.
Appropriate technologies are selected in accordance with the learning context.	Implementing blended learning activities.	Implementing blended microlearning lessons.
Learning materials are accessible across all devices based on learners' needs.	Monitoring and assessing learning outcomes.	Monitoring and assessing learning progress.
Learners are allowed to review and revisit the learning content as needed.	Reflecting on and improving learning by analyzing learning data and feedback to enhance content and instructional processes.	Reflecting on and improving the learning process.

Table 3. Results of the expert evaluation of the synthesized learning model

Evaluation Items	M	S.D.	Level of Appropriateness
Overall appropriateness of the conceptual framework	5.00	0.00	Highest
Appropriateness of the instructor's role	4.80	0.42	Highest
Appropriateness of the learner's role	4.80	0.42	Highest
Appropriateness of the instructional model	5.00	0.00	Highest
Appropriateness of digital skills assessment	4.90	0.32	Highest
Appropriateness of the rubric score as a digital skills assessment tool	4.80	0.42	Highest
Appropriateness of lesson organization based on the microlearning model integrated with blended learning via an online learning platform	4.90	0.32	Highest
Appropriateness of learning activities	5.00	0.00	Highest
Overall appropriateness of the developed learning model	4.90	0.32	Highest
Appropriateness of applying the learning model in real practice	5.00	0.00	Highest
Total	4.91	0.29	Highest

a) Analysis

- (1) Digital-skill lesson plan (six units): (1) Digital media production for instructional purposes; (2) Internet literacy and use; (3) Educational use of social media; (4) Use of tools for student measurement and assessment; (5) Technology-enhanced instructional management; and (6) Ethical and responsible media use. The plan was structured for six weeks at 4 hours per week with a 50:50 online–offline blend. Appropriateness was evaluated by five experts using a five-point rating scale; the plan was rated highly appropriate ($M = 4.89$, $SD = 0.31$).
- (2) Digital-knowledge test (60 items): A 60-item test covering all six units was administered as both a pretest and posttest. Content validity was examined via the index of item–objective congruence (IOC) by five experts; all items met the criterion of $IOC \geq 0.80$. Item difficulty (p) ranged from 0.63 to 0.80, and the reliability of the test, $KR-20 = 0.88$.
- (3) Unit worksheets (six units): Performance on each unit worksheet was assessed with a five-level analytic rubric. Appropriateness was evaluated by five experts using a five-point standard; the rubric was rated highly appropriate ($M = 4.86$, $SD = 0.35$).

b) Design

- (1) Design of the Online Learning Platform Workflow A platform workflow was designed to support the microlearning integrated blended instructional model aimed at enhancing pre-service teachers' digital skills. The platform serves two user groups: instructors and learners and its scope encompasses the following functions: new-user registration for both learners and instructors; classroom creation; course creation; worksheet creation; test/quiz creation; lesson content import; and test result display.
- (2) Design of Microlearning Materials (Six Units): Six microlearning units were developed, each integrating

images, narrated audio, demonstration videos, and accompanying instructional documents. The microlearning design in this study was structured to segment learning content into concise and manageable units. Each unit consisted of two main components: conceptual content and procedural demonstration. The conceptual content was presented using infographic-based materials, organized into smaller segments to facilitate focused attention and comprehension. Procedural knowledge was supported through step-by-step demonstration videos, allowing learners to observe the application of concepts in practice. To manage cognitive load, content was presented in a structured and concise format, and video duration was limited to no more than 5 min. Multimedia elements, including infographics and demonstration videos, were integrated to support clarity, engagement, and progressive understanding of the learning content.

c) Development

- (1) Developed the online learning platform, which was evaluated for appropriateness by five experts. Black-box testing was employed as the assessment method. The platform was rated highly appropriate ($M = 4.88$, $SD = 0.32$).
- (2) Developed six microlearning units, which were evaluated for media quality by five experts. The materials were rated excellent ($M = 4.96$, $SD = 0.20$).

d) Implement

In this stage, the researcher implemented the expert-validated development with the target sample following a pre-experimental design. The implementation proceeded in two parts: (1) determining the instructional efficiency of the model and (2) piloting the model to examine pre-service teachers' digital skills. A preliminary try-out was conducted with 33 pre-service teachers at Nakhon Pathom

Rajabhat University, selected via simple random sampling and then allocated to three groups stratified by prior test performance (mixed high/medium/low): a small group ($n = 3$), a medium group ($n = 6$), and a large group ($n = 24$). The trial spanned three weeks and was used to estimate instructional efficiency according to the E1/E2 criterion and to refine the model based on formative feedback. Research Instruments: (1) Microlearning integrated blended instructional model via an online platform to enhance pre-service teachers' digital skills; (2) Digital-skill lesson plans (six units); (3) Digital-knowledge test (60 items); and (4) Unit worksheets (six units).

e) Evaluation

Following the try-out, the instructional efficiency (E1/E2) results were as follows:

Table 4. Efficiency evaluation results for a small group

Assessment	n	Score	Total Score	Efficiency
Learning process (E1)	3	60	152	84.44
Post-test (E2)	3	60	163	90.56

Table 5. Efficiency evaluation results for a medium group

Assessment	n	Score	Total Score	Efficiency
Learning process (E1)	6	60	305	84.72
Post-test (E2)	6	60	321	89.17

Table 6. Efficiency evaluation results for a large group

Assessment	n	Score	Total Score	Efficiency
Learning process (E1)	24	60	1233	85.63
Post-test (E2)	24	60	1293	89.79

These findings of Tables 4–6 indicate that the developed instructional model achieved satisfactory efficiency and is suitable for implementation in the full experiment.

3) Phase 3: Experiment and data collection

Procedural Steps: six weeks (4 hours/week) using a 50:50 online–offline blend.

- (1) Convene the 268 participant–learners, explain the study, the voluntary nature of participation, and obtain informed consent.
- (2) Brief participants on the instructional model and provide an orientation to the online learning platform as shown in Table 7.

Table 7. Weekly learning procedures

Week	Detail
1	1. Administer the digital-knowledge pretest (60 items). 2. Administer the pre-learning worksheet for Unit 1. 3. Deliver content via the online platform; upon completion, administer the formative in-lesson quiz. 4. Participants complete the unit worksheet. 5. Report worksheet scores in the following week.
2–5	1. Administer the pre-learning worksheet Units 2, 3, 4, 5. 2. Deliver content via the online platform; upon completion, administer the formative in-lesson quiz. 3. Participants complete the unit worksheet. 4. Report worksheet scores in the following week.
6	1. Administer the pre-learning worksheet for Unit 6. 2. Deliver content via the online platform; upon completion, administer the formative in-lesson quiz. 3. Participants complete the unit worksheet. 4. Report worksheet scores in the following week. 5. Administer the digital-knowledge posttest (60 items).

Digital skills were assessed using two types of instruments. First, a digital knowledge test consisting of 60 multiple-choice items was developed to measure students' declarative knowledge of digital skills. The test was

administered as both a pretest and a posttest. Second, performance-based digital skills were assessed through structured classroom worksheets, with one worksheet assigned per learning unit. Each worksheet was scored on a 10-point scale using an analytic rubric. The analytic rubric included multiple criteria covering task performance, quality of output, and responsible work practices, aligned with the targeted digital skill domains. All performance assessments were conducted by a single trained instructor using the analytic rubric to ensure consistency in scoring.

D. Procedure

This study employed a one-group pretest–posttest design over six weeks (4 h per week). The detailed instructional procedures and data collection process are described in Phase 3. The implementation of the MB Learning Model was supported by a web-based learning platform, as described below.

The online learning platform was developed as a web-based system using WordPress to support the implementation of the MB Learning Model. The system provides a structured and interactive learning environment in which students can access instructional content, complete assessments, and receive feedback within a single interface. Upon logging into the system, learners can monitor their learning progress through a dashboard displaying completion status and performance. Notification features are also provided to inform learners of newly available lessons and instructor feedback.

The learning process begins with a pretest assessing baseline digital knowledge, followed by progression through six microlearning units. Within each unit, learners complete formative quizzes and subsequently perform performance-based tasks through structured worksheets submitted via the platform.

The platform includes both automated and instructor-mediated feedback mechanisms. For selected performance-based tasks—specifically digital media production for instructional purposes and the use of tools for student measurement and assessment—learners receive qualitative feedback and are allowed one revision opportunity. This approach was applied only to these tasks due to their higher level of complexity and multidimensional evaluation criteria, including content accuracy, visual design quality, and the logical sequencing of information. In contrast, other tasks follow more structured procedures with clearly defined expected outcomes, allowing for direct assessment without iterative revision. In addition, the system records and stores both knowledge test scores and performance-based assessment results, enabling instructors to monitor learner progress and evaluate outcomes.

This integrated system design supports a continuous learning workflow that connects instruction, assessment, feedback, and progress tracking within a unified environment.

E. Data Analysis

Descriptive statistics, including mean and standard deviation, were used to summarize the results of the instructional model, lesson plans, worksheets, and the online learning platform.

The quality of the instruments was evaluated prior to data

collection. Content validity was assessed using the Index of Item-Objective Congruence (IOC), with all items meeting the criterion of $\text{IOC} \geq 0.80$. Item difficulty (p) ranged between 0.20 and 0.80, and internal consistency reliability of the knowledge test was confirmed using the Kuder–Richardson Formula 20 (KR-20), with a coefficient of ≥ 0.80 .

Instructional efficiency was evaluated using the E1/E2 criterion, a commonly used metric in Thai educational research. E1 represents the efficiency of the learning process, calculated from learners' performance during instructional activities, while E2 represents the efficiency of learning outcomes, measured by posttest performance. The 80/80 benchmark is a conventional standard in Thailand, indicating that learners achieve at least 80% performance during instruction and 80% on post-instruction assessments. In this

study, the E1/E2 values were used as an index of alignment between instructional activities and learning outcomes.

IV. RESULTS

A. Development of the MB Learning Model

The synthesized instructional model, hereafter termed the MB Learning Model in Fig. 1, integrates microlearning with blended delivery on an online platform. The model structures instruction into short, self-contained subtopics that provide complete essential content in 3–5 min per segment. Learners study each synthesized micro-unit via the platform and then engage in guided practice with performance-based assessment of their products.

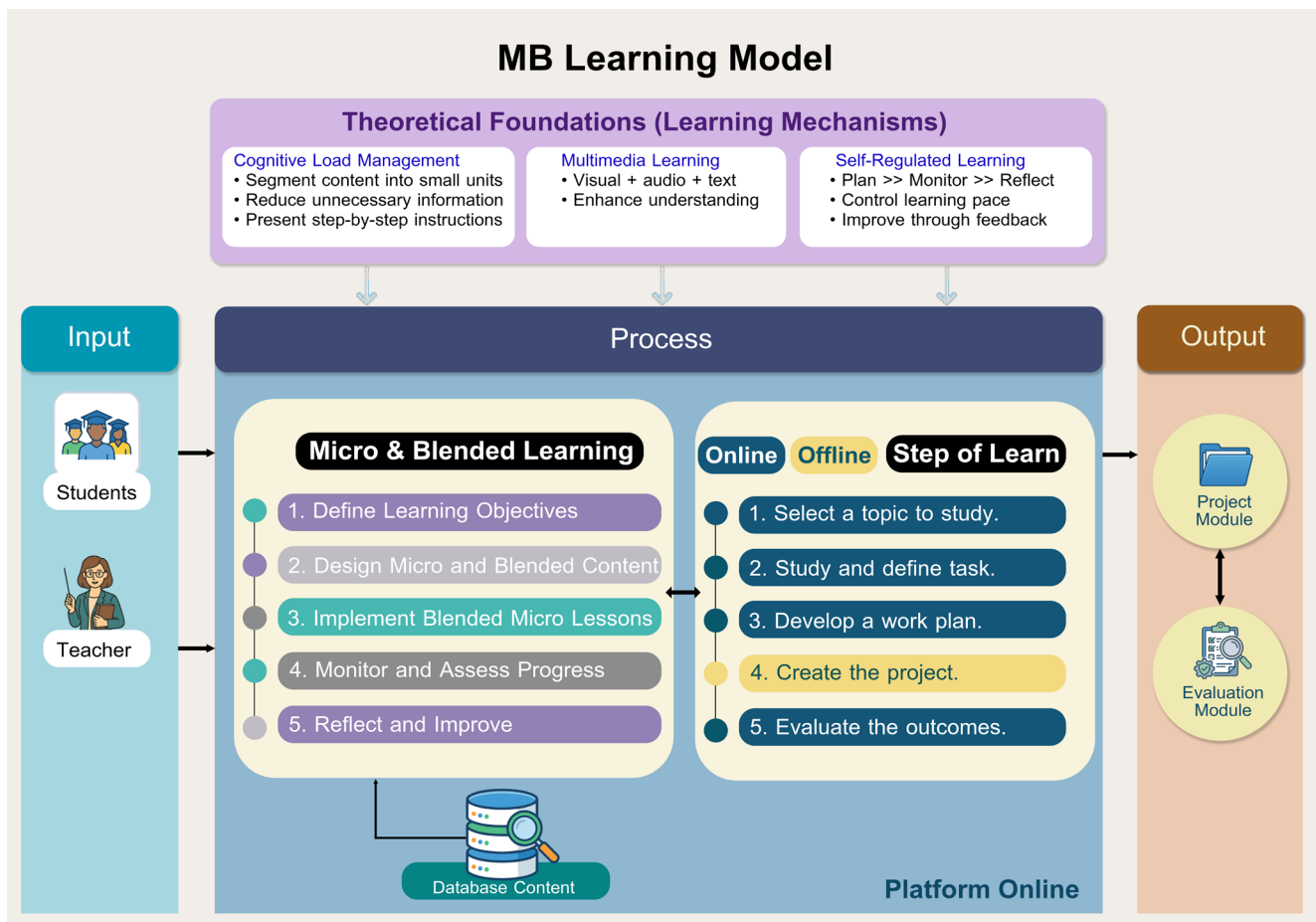


Fig. 1. Presentation of the MB learning model.

The MB Learning Model is an instructional model developed through the synthesis of microlearning and blended learning concepts to enhance the digital skills of pre-service teachers via an online learning platform, as illustrated in Fig. 1. The model emphasizes the delivery of content in structured micro-units with short learning durations (3–5 min), each aligned with specific learning objectives. This design enables learners to study flexibly at their own pace while maintaining systematic continuity of content.

A key feature of the model is the design of a sequential and interconnected learning process, beginning with topic selection and content learning, followed by task implementation and evaluation. This structure supports learners in effectively linking knowledge acquisition with

practical application. In addition, the model incorporates a dual-mode learning process consisting of online and offline components. The online component focuses on understanding, analysis, and planning, whereas the offline component emphasizes hands-on practice, thereby bridging theoretical knowledge with real-world application.

Furthermore, the model highlights continuous assessment and iterative feedback, allowing learners to submit their work, receive evaluation, and reflect on their learning through the platform. This demonstrates a comprehensive and continuous instructional design process.

Procedures for implementing the microlearning-integrated blended model via an online platform to enhance pre-service teachers' digital skills.

(1) Learners log in, select the classroom, and choose a topic.

- (2) Learners study the microlearning content as designed by the instructor, following a blended sequence with online and offline components:

Online: (a) select a topic; (b) study the content and define the task; (c) develop a work plan; (d) evaluate outcomes.

Offline: create the project (hands-on production).

- (3) Learners complete the worksheet for the unit and submit it on the platform.

- (4) Learners receive feedback and scores.

Unlike conventional implementations, where microlearning and blended learning are applied as loosely connected components, the MB Learning Model explicitly structures their integration within a coherent instructional process. This structured alignment ensures that microlearning units are not isolated content fragments but are systematically embedded within a continuous learning sequence that links content delivery, practice, and assessment.

B. Instructional Efficiency of the MB Learning Model

To determine instructional efficiency, data were collected during instruction from 268 learners via in-process quizzes and a post-learning test. The resulting data were analyzed to compute the efficiency indices (E1/E2), as summarized in Table 8.

Table 8. Efficiency results (E1/E2) of the microlearning-integrated blended learning model delivered via an online platform to enhance pre-service teachers' digital skills

Assessment	n	Score	M	SD	Total Score	Efficiency
In-process learning (E1)	268	60	54.53	1.78	14,614	90.88
Posttest (E2)	268	60	52.06	2.04	13,951	86.76

E1 (in-process learning score) represents learners' performance on worksheet-based assessments during instruction (maximum score = 60), while E2 (posttest score) reflects performance on the digital knowledge test

administered after instruction (maximum score = 60). The E1 mean score (54.53) is derived from the same worksheet-based performance assessment data used to calculate the overall post-learning digital skills composite.

From Table 8, the microlearning-integrated blended model delivered via an online platform achieved E1/E2 values of 90.88/86.76, exceeding the conventional 80/80 benchmark. This suggests that the instructional activities and learning outcomes were well aligned.

While the E1/E2 efficiency criterion provides a useful index of instructional efficiency within the Thai educational research context, it is not widely adopted in international educational research. Therefore, the results should be interpreted alongside other indicators, such as statistically significant improvements and performance-based assessment outcomes, to provide a more comprehensive evaluation of instructional impact.

Accordingly, the E1/E2 values reported in this study are presented as supplementary evidence rather than as a sole indicator of instructional effectiveness.

C. Post-learning Digital Skill Outcomes

This section presents the results from two complementary assessment instruments used to evaluate pre-service teachers' digital skills.

First, Table 9 reports the results of the digital knowledge test, which consisted of 60 multiple-choice items administered before and after instruction to measure declarative knowledge of digital skills.

Second, Table 10 presents the results of performance-based assessments derived from six worksheets (one per skill domain). Each worksheet was evaluated using an analytic rubric with a maximum score of 10 points per domain, reflecting students' practical digital skill performance.

Table 9. Digital-knowledge test

Assessment	n	M	SD	MD	t(df)	p	d	df
Pretest	268	27.60	3.13	24.46	107.90	<0.001	6.59	267
Posttest	268	52.06	2.04					

From Table 9, the knowledge test comprised 60 items, administered pre- and post-instruction with the same instrument. Values are means and standard deviations. The analysis used paired two-tailed t-tests with N = 268 matched

cases. "Mean diff" is the pre-post mean difference. Larger scores indicate greater declarative knowledge. All *p*-values are two-tailed and rounded to three decimals; other statistics are rounded to two decimals.

Table 10. Pre-post digital skills by domain

Skill domain	Pre (M)	SD	Post (M)	SD	MD	t(267)	p	d
Digital media production for instructional purposes	6.32	0.52	9.11	0.65	2.79	55.40	< 0.001	3.39
Internet literacy and use	6.58	0.50	9.04	0.66	2.46	48.70	< 0.001	2.97
Educational use of social media	6.82	0.46	9.08	0.62	2.26	47.00	< 0.001	2.87
Use of tools for student measurement and assess	6.53	0.50	9.07	0.67	2.54	49.30	< 0.001	3.01
Technology-enhanced instructional management	6.49	0.50	9.08	0.65	2.59	52.50	< 0.001	3.21
Ethical and responsible media use	6.78	0.43	9.15	0.64	2.37	49.50	< 0.001	3.02
Overall digital skills	39.52	1.29	54.53	1.78	15.01	115.11	< 0.001	7.03

From Table 10, each domain score is based on a 10-point analytic rubric. The overall digital skills score represents the sum of six domains (maximum = 60) and is distinct from the knowledge test scores reported separately. Six performance-based digital-skill domains were assessed using analytic rubrics scaled from 0 to 10 per domain. The "Overall digital skills" score is the sum of these six domains (range 0–60). Values are presented as means and standard

deviations. Paired two-tailed t-tests were conducted with N = 268 matched cases. Mean Difference (MD) refers to the difference between posttest and pretest scores. Higher scores indicate stronger performance in the target skills. All *p*-values are two-tailed and reported to three decimal places; other statistics are reported to two decimal places.

The resulting data were analyzed to obtain the relevant statistics, as summarized in Fig. 2.

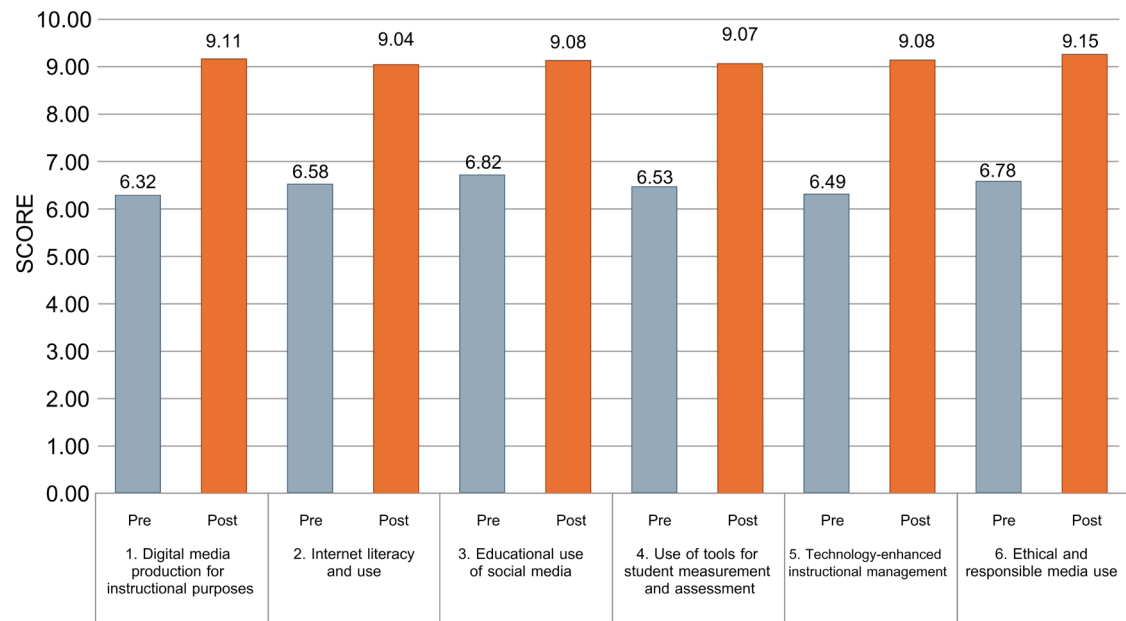


Fig. 2. Results of the assessment of pre-service teachers' digital-skill levels.

From Fig. 2, the pre-performance and post-performance on each digital skill were evaluated using unit worksheets scored on a 10-point scale, with proficiency levels defined as follows:

Level 4 (Excellent) = 9–10 (high quality, complete);

Level 3 (Good) = 7–8 (meets standards, minor errors);

Level 2 (Fair) = 5–6 (adequate, some omissions);

Level 1 (Below Standard) = 0–4 (major omissions, needs improvement).

Post-learning mean scores by skill were: Digital media production for instructional purposes, $M = 9.11$; Internet literacy and use, $M = 9.04$; Educational use of social media, $M = 9.08$; Use of tools for student measurement and assessment, $M = 9.07$; Technology-enhanced instructional management, $M = 9.08$; and Ethical and responsible media use, $M = 9.15$.

Ranking the six skills indicated that the highest post-learning performance was in ethical and responsible media use, followed by digital media production, educational use of social media, technology-enhanced instructional management, use of tools for student measurement and assessment, and internet literacy and use. Across the six domains, the average score increased from $M = 6.59$ to $M = 9.09$, corresponding to Level 4 (Excellent), indicating high-quality and complete performance.

V. DISCUSSION

A. Model Development

Input: learner and instructor roles.

Process: the instructional workflow supported by a content repository. Instructors design teaching materials and content using a microlearning approach (five-step media-creation procedure) and deliver them in a blended format via an online learning platform. The learning sequence comprises online and offline components: Online: (1) select a topic to study; (2) study the content and define the task/objectives; (3) develop a work plan; (4) evaluate outcomes. Offline: (5) create the project (hands-on production).

Output: learners produce artifacts and submit them through

the platform; products are assessed using evaluation rubrics, specifically analytic rubrics.

The instructional model is referred to as the MB Learning Model. To design a model suitable for real classroom implementation, the researcher reviewed relevant theories, documents, and prior studies, and then developed the model following the ADDIE framework to enhance effectiveness and ensure appropriateness. The ADDIE stages are: (1) Analyze, (2) Design, (3) Develop, (4) Implement, and (5) Evaluate.

While previous studies have examined microlearning, blended learning, and online platforms as separate or loosely connected approaches, the MB Learning Model systematically combines these components within a unified web-based instructional environment. The model connects microlearning content, blended instructional activities, formative assessment, and performance-based evaluation through a continuous learning sequence.

The instructional process begins with a pretest assessing baseline digital knowledge, followed by participation in six microlearning units. Within each unit, learners complete formative quizzes and performance-based tasks submitted and evaluated through the platform. This structure links knowledge acquisition with practical digital skill development while supporting continuous feedback and learner engagement.

The model contributes to teacher education by providing a practically applicable framework that integrates microlearning design, blended learning implementation, and authentic performance assessment to support digital skill development among pre-service teachers. Although the model conceptually includes multiple assessment approaches, only analytic rubrics were implemented in the present study, and all reported findings are based solely on analytic rubric scores.

B. Instructional Efficiency

The experimental evaluation showed that the developed model achieved $E1/E2 = 90.88/86.76$, exceeding the established 80/80 benchmark. This outcome is attributable to

the rigorous development of instruments aligned with the model's objectives for enhancing pre-service teachers' digital skills, including expert review to ensure measurement quality. In-process worksheet scores tended to be higher than the post-learning assessment, likely because learners completed the worksheets immediately after instruction, without a delay interval, which may have produced short-term performance gains. These findings are consistent with previous studies reporting that microlearning-based instructional approaches can improve learners' knowledge and engagement [36].

C. Digital Skill Development

Experimental results showed that, after learning with the developed model, pre-service teachers' post-learning means across all six skills were at the Excellent level. Ordered by mean score, the results were: (1) ethical and responsible media use ($M = 9.15$); (2) digital-media production for instructional purposes ($M = 9.11$); (3) educational use of social media and technology-enhanced instructional management (both $M = 9.08$); (4) use of tools for student measurement and assessment ($M = 9.07$); and (5) internet literacy and use ($M = 9.04$). The assessment rubric and worksheets were developed in accordance with academic standards and underwent expert review for appropriateness, followed by revisions prior to implementation. Importantly, these high post-learning levels were accompanied by large pre-post gains across domains (paired t-tests, $N = 268$, all $p < 0.001$). The overall digital-skills composite likewise increased, indicating broad-based, practically significant improvement in performance. Convergent evidence from the knowledge test also supports the effectiveness of the model: scores rose from ($M = 27.60$, $SD = 3.13$) at pretest to ($M = 52.06$, $SD = 2.04$) at posttest. The microlearning-integrated blended approach on an online platform, short in duration, age-appropriate, presented in an accessible language, available anytime, anywhere, and readily reviewable, likely contributed to these outcomes.

From a theoretical perspective, the findings can be interpreted through the mechanisms proposed by Cognitive Load Theory, Multimedia Learning Theory, and Self-Regulated Learning. The segmentation of content into short microlearning units likely reduced extraneous cognitive load by allowing learners to process information in smaller and more manageable segments. This structured presentation may have supported more efficient information processing and retention of essential concepts during learning activities.

In addition, the integration of infographic-based materials and demonstration videos supported multimedia processing by combining visual, textual, and procedural information within concise learning sequences. This design may have facilitated learners' comprehension of complex digital tasks and supported the transfer of conceptual understanding into practical performance. The online learning platform also supported self-regulated learning processes by enabling learners to monitor progress, revisit learning materials, manage learning pace, and respond to feedback throughout the instructional process. These mechanisms likely contributed to sustained learner engagement and continuous improvement in performance-based digital skills across the six learning domains. The findings align with Phitthayasenee *et al.* [37], who proposed a

competency-development framework for pre-service teachers at Rajabhat Universities, sequencing competencies by Bloom's Taxonomy across three domains: cognitive (244 indicators), psychomotor (244 indicators), and affective (244 indicators). For first-year pre-service teachers, mean perceived digital-technology competencies ranked from lowest to highest were: Domain 2: Information Access ($M = 3.91$, 78.13%); Domain 5: Use of Digital Technology in Teaching ($M = 4.00$, 79.93%); and Domain 1: Foundational Knowledge of Media and Digital Technology ($M = 4.23$, 84.67%).

It should be noted that the observed effect sizes were relatively large compared to those commonly reported in educational intervention research. This may be partly attributable to the measurement characteristics of the analytic rubrics used in this study. Because performance scores were derived from constrained scoring ranges and post-learning scores clustered near the upper end of the scale, score variability was relatively limited, which may have inflated standardized effect size estimates. Therefore, the reported Cohen's d values should be interpreted with caution and not directly compared with effect sizes derived from broader-range standardized instruments.

Although the results indicate substantial improvements in digital skills following the implementation of the MB Learning Model, these findings should be interpreted with caution due to the use of a one-group pretest-posttest design. Such a design may overestimate learning gains because it does not control for potential confounding factors, including maturation effects, repeated testing effects, and increased familiarity with assessment tasks. However, in this study, the posttest was administered only once at the end of the six-week intervention, which may partially reduce the influence of repeated testing on posttest performance. In addition, participants were selected using cluster random sampling from multiple teacher education programs, which helps enhance sample diversity and reduce selection bias. Nevertheless, compared to experimental or quasi-experimental designs that include control or comparison groups, the present design provides limited evidence for establishing causal relationships between the instructional model and observed outcomes.

Therefore, the reported improvements should be interpreted as indicative of an association rather than a definitive causal impact. Future research employing more rigorous designs, such as randomized controlled trials or quasi-experimental approaches, would provide stronger evidence for validating the effectiveness of the MB Learning Model.

D. Limitations

This study has several limitations that should be acknowledged. First, the use of a one-group pretest-posttest design without a control or comparison group limits the ability to draw causal conclusions. The observed improvements in digital skills may have been influenced by external factors such as maturation, repeated testing effects, or increased familiarity with the learning tasks.

Second, the study was conducted within a single institutional context, which may limit the generalizability of the findings to other educational settings or populations.

Future studies involving multiple institutions or diverse learner groups would strengthen external validity.

Third, the assessment instruments, including the performance-based rubrics and knowledge test, were developed by the researchers. Although these instruments were validated by experts, there remains a possibility of measurement bias or limited sensitivity in capturing variations in learners' performance. Furthermore, inter-rater reliability was not calculated because all performance assessments were conducted by a single instructor. This may limit the objectivity and reliability of the scoring process.

Fourth, the post-learning scores across digital skill domains were relatively high and clustered within a narrow range, which may indicate a potential ceiling effect. This suggests that the assessment tools may have limited ability to discriminate among higher levels of performance.

Finally, the study did not include a delayed posttest to examine the retention of digital skills over time. Future research should consider longitudinal designs to evaluate the sustainability of learning outcomes.

A key limitation of this study is the use of a pre-experimental one-group pretest-posttest design, which limits the ability to establish causal relationships between the instructional model and observed learning outcomes. Future research should employ experimental or quasi-experimental designs with control groups to provide stronger evidence of instructional effectiveness.

VI. CONCLUSION

This study culminated in the development of an instructional model entitled the MB Learning Model. Instructors design teaching materials and content using a microlearning approach, operationalized through five steps: (1) Define Learning Objectives; (2) Design Micro and Blended Content; (3) Implement Blended Micro Lessons; (4) Monitor and Assess Progress; and (5) Reflect and Improve. When implemented as blended learning via an online platform, the learning sequence is organized into online and offline components in accordance with the blended format.

Based on these findings, several practical and research-related recommendations may be considered to support future implementation and further development of digital skill instruction in teacher education contexts.

- (1) Future research should employ experimental or quasi-experimental designs with control or comparison groups to strengthen causal inference regarding the effectiveness of the MB Learning Model.
- (2) Further studies should examine the application of the MB Learning Model across multiple institutions and diverse learner populations to enhance the generalizability of the findings.
- (3) Future research should incorporate more sensitive and discriminative assessment tools to reduce potential ceiling effects and better capture variations in higher-level digital skills.
- (4) Longitudinal studies should be conducted to investigate the retention and transfer of digital skills over time following the implementation of the MB Learning Model.
- (5) Future research may explore the integration of learning

analytics and platform-based data to further examine learner engagement and learning processes within the MB Learning Model.

Although this study was conducted within the context of pre-service teachers at a Rajabhat University in Thailand, the instructional design principles underlying the MB Learning Model are not context-specific. The integration of microlearning, blended learning, and platform-based instruction reflects broader pedagogical approaches that are widely applicable in teacher education.

The emphasis on structured instructional design, performance-based assessment, and digital skill development aligns with international trends in preparing teachers for technology-enhanced learning environments. Therefore, while the specific implementation reflects a local context, the underlying framework and design principles may be adaptable to other educational settings with similar goals.

These findings contribute to the growing body of research on technology-enhanced learning by providing an operational framework for integrating microlearning within blended learning environments in teacher education.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

PS and US contributed equally to this research. US conceptualized the study framework, designed the research framework, developed the research instruments, and analyzed the data. PS conceptualized the research framework, developed the research instruments, conducted the pilot study, collected the data, and analyzed the data. Both authors jointly reviewed relevant literature, prepared the manuscript, and approved the final version of the manuscript.

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