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A phenomenon-based learning management model integrating a digital learning ecosystem to enhance metacognition for pre-service teachers

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Abstract

This research aimed to: 1) investigate the metacognition learning achievement of students taught using a phenomenon-based learning management model integrating a digital learning ecosystem; 2) examine the learning gain and compare pre- and post-metacognition learning achievement of students taught using a phenomenon-based learning management model integrating a digital learning ecosystem to enhance metacognition for pre-service teachers; and 3) explore students' opinions towards the phenomenon-based learning management model integrating a digital learning ecosystem to enhance metacognition for pre-service teachers. The sample group comprised 30 mathematics major students from the Faculty of Education at a public university in Northeastern Thailand, enrolled in the second semester of the 2024 academic year, selected through cluster random sampling. The research instruments included phenomenon-based learning management plans integrating a digital learning ecosystem, a metacognition learning achievement test, and a questionnaire. Data were analyzed using mean, standard deviation, learning gain analysis, and dependent sample t-test. The research findings revealed that: 1) the mean percentage score of metacognition learning achievement after learning through the phenomenon-based learning management model integrating a digital learning ecosystem was 80.25%; 2) the normalized gain of the whole class was at a medium level (<g>=0.64), and the post-test mean score of metacognition learning achievement was significantly higher than the pre-test mean score at the 0.01 level of statistical significance; and 3) students' opinions towards the phenomenon-based learning management model integrating a digital learning ecosystem were at a high agreement level.

Keywords: Digital learning ecosystem, Learning achievement, Metacognition, Phenomenon-based learning, Pre-service teachers.

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Contents

Contribution of this paper to the literature

This study contributes to the existing literature by integrating phenomenon-based learning with a digital ecosystem. The paper's primary contribution is identifying significant gains in pre-service teachers' metacognition compared to conventional instruction. This study provides mixed-methods evidence that real-world phenomena combined with digital tools result in measurable learning gains.

1. Introduction

Learning in real-life contexts should not be confined to the traditional school setting, delimited by school hours and academic semesters. In the 21st century, learning must transcend conventional mindsets, practices, schedules, and locations, becoming deeply interconnected with authentic life experiences (Kennedy & Sundberg, 2020). Consequently, educational approaches must prioritize learning methodologies that connect with phenomenon-based education, fostering genuine real-world learning (Krajcik & Czerniak, 2018). This involves exploring and linking real-world phenomena with theoretical knowledge, culminating in reports and knowledge exchange through the internet, thereby cultivating broad and expansive relationships. Experience-based learning empowers learners to venture beyond the confines of the classroom, enabling them to acquire diverse knowledge and skills, particularly 21st-century competencies (Jullien & Kolb, 1984). This approach emphasizes authentic learning experiences, moving away from a narrow focus on rote memorization for examinations or simply attending school.

Internet-based learning further facilitates learners' expansion beyond conventional educational boundaries. When educators guide students in experiential learning and knowledge sharing via the internet, utilizing a digital learning ecosystem framework (Huang, Li, Huang, & Jiang, 2023), it cultivates metacognition, promotes deep learning, and empowers students to construct their own knowledge (Flavell, 1979). This signifies learning that transcends the limitations of classrooms and fixed schedules, emphasizing the necessity of lifelong learning in the digital age of the 21st century. Whenever feasible, students should engage in both cooperative and collaborative learning, encouraging collective thinking and action towards the attainment of shared learning objectives (Veldman & Kostons, 2019).

Therefore, phenomenon-based learning is effectively integrated within a digital learning ecosystem (Adipat, 2024). In this context, it is imperative that pre-service teachers are developed through phenomenon-based learning in conjunction with an integrated educational approach incorporating a digital learning ecosystem to enhance metacognition (Louca & Zacharia, 2012; Schraw & Dennison, 1994).

As a lecturer in Curriculum and Instruction at the Faculty of Education, Nakhon Phanom University, the researcher has examined learning management plans and the development of metacognition learning achievement. It has been concluded that phenomenon-based learning and place-based education serve as valuable instruments for developing pre-service teachers at the Faculty of Education, Nakhon Phanom University. This is intended to equip them for their own continuous learning and their future roles as teachers who promote and support responsibilities in the teaching profession. Specifically, students will gain knowledge and understanding of phenomenon-based learning and place-based education integrated with digital technologies, which they can apply to manage learning for their own students and cultivate 21st-century skills. To this end, the researcher has established the following research objectives.

To provide a clear overview, this paper is organized as follows. The next section reviews relevant literature on phenomenon-based learning, digital learning ecosystems, and metacognition. This is followed by the research methodology, including participants, instruments, and procedures. The subsequent section presents the research findings, which are then discussed in relation to previous studies and theoretical frameworks. Finally, the paper concludes with implications for teacher education, recommendations for practice, and directions for future research.

2. Literature Review

2.1. Phenomenon-Based Learning

Phenomenon-Based Learning originated from Finland's educational reforms, aiming to transcend fragmented subject-based teaching and shift toward integrated learning experiences closely connected to the real world. Its core lies in guiding students to engage with authentic phenomena, thereby fostering interdisciplinary connections, critical inquiry, and active knowledge construction (Østergaard, Lieblein, Breland, & Francis, 2010). Phenomenon-Based Learning helps bridge the gap between theoretical knowledge and practical application, enabling students to perceive the relevance of learning content to their daily lives. A growing body of empirical research validates its potential for enhancing learning outcomes and cognitive development. Studies indicate it effectively improves students' critical thinking, scientific explanation skills, creativity, and metacognitive awareness (Pareken, Patandean, & Palloan, 2015; Pratiwi, Copriady, & Anwar, 2021). For instance, experimental studies comparing Phenomenon-Based Learning with traditional instruction found that students engaged in phenomenon-driven learning demonstrated significant improvements in analytical skills and conceptual understanding (Pareken et al., 2015). Furthermore, Phenomenon-Based Learning has been applied across diverse fields, including science, technology, language education, and elementary education (Islakhiyah, Sutopo, & Yulianti, 2017; Wakıl, Rahman, Hasan, Mahmood, & Jalal, 2019). Scholars also note that integrating PBL with other instructional models can further amplify its advantages (Tongsoong & Jermtaisong, 2021).

2.2. Digital Learning Ecosystem

The concept of the digital learning ecosystem is increasingly recognized as a vital framework for enhancing educational experiences. Its theoretical foundation stems from ecological thinking, emphasizing the interplay and holistic nature of multiple elements within educational systems. For instance, museum education can be understood as a learning ecosystem comprising collections, spaces, personnel, audiences, and intricate networks of interactions elements that collectively sustain the museum's educational functions (Sabiescu & Charatzopoulou, 2018). Numerous studies highlight the unique value of digital learning ecosystems in structural integration and educational continuity. At the application level, these ecosystems demonstrate significant effectiveness in language

learning, teacher professional development, and higher education innovation. Research indicates that digital learning ecosystems can effectively enhance pre-service teachers' learning experiences and outcomes within blended learning models, demonstrating targeted advantages in acquiring specific language skills like phonetics and phonology (Pinto-Llorente, 2020, 2022). Regarding teacher professional development, digital learning ecosystems highlight their crucial role in continuous professional growth and capacity building (Donnelly & Maguire, 2020). At the higher education level, they can meet diverse needs and drive educational innovation (Bhatnagar, Khanna, & Rana, 2021).

2.3. Metacognition

The concept of metacognition has garnered significant scholarly attention since its inception, particularly in understanding how individuals, including children and learners, regulate and monitor their cognitive processes. Early research efforts not only revealed the multidimensional nature of metacognition but also highlighted challenges in its measurement. Research on children's reading comprehension has emphasized the challenges of operationalizing metacognition, proposing the "Index of Reading Awareness" (IRA) as an informal measurement tool to capture children's understanding of the reading process (Jacobs & Paris, 1987). Research has also reviewed the application of metacognitive strategies in educational theory and practice, highlighting their crucial role in enhancing learning outcomes (Hacker, Dunlosky, & Graesser, 1998). As research deepens, scholars continue to expand their understanding of metacognition from diverse disciplinary perspectives. Neurocognitive research reveals its close connection to executive functions, suggesting that higher cognitive processes such as attention, conflict resolution, and emotional regulation depend on prefrontal activity, thereby demonstrating the biological basis of metacognition (Shimamura, 2000). Comparative psychology has extended metacognitive research beyond humans (Smith, Shields, & Washburn, 2003). Empirical research in education and psychology further focuses on measuring metacognition and individual differences (Sperling, Howard, Staley, & DuBois, 2004). In educational practice, metacognitive strategies have been demonstrated to significantly enhance understanding and critical thinking in science and mathematics learning through question generation and anomaly detection (Hacker, Dunlosky, & Graesser, 2009).

2.4. Research Objectives

1. To investigate the metacognition learning achievement of students taught using a phenomenon-based learning management model integrating a digital learning ecosystem.
2. To examine the learning gain and compare the pre- and post- metacognition learning achievement of students taught using a phenomenon-based learning management model integrating a digital learning ecosystem to enhance metacognition for pre-service teachers.
3. To explore students' opinions regarding the phenomenon-based learning management model that integrates a digital learning ecosystem to enhance metacognition for pre-service teachers.

2.5. Research Hypotheses

1. Pre-service teachers who receive learning management using a phenomenon-based learning management model integrating a digital learning ecosystem will achieve a mean score of metacognitive learning achievement at or above 80 percent.
2. Pre-service teachers who receive learning management using a phenomenon-based learning management model integrating a digital learning ecosystem will demonstrate post-test metacognition learning achievement scores that are significantly higher than their pre-test scores.

3. Methodology

This research, entitled "A Phenomenon-Based Learning Management Model Integrating a Digital Learning Ecosystem to Enhance Metacognition in Pre-service Teachers," employed a mixed-methods approach. The experimental phase utilized a basic experimental research design, specifically a One-Group Pretest-Posttest Design (Campbell & Stanley, 1963), classified as pre-experimental research. This design involved a single group undergoing both pre- and post-testing (Figure 1).

$$O_1 \quad X \quad O_2$$

Figure 1. Research design: O1–X–O2 (Pretest–treatment–posttest).

O1 = Pretest (Pre-knowledge Assessment).

X = Phenomenon-Based Learning Management Model Integrating a Digital Learning Ecosystem (Experimental Treatment).

O2 = Posttest (Post-knowledge Assessment).

3.1. Scope of the Research

3.1.1. Population and Sample

1. The population consisted of pre-service teachers in the Faculty of Education at Nakhon Phanom University during the 2024 academic year. This included pre-service teachers from each major, with two groups per major: Mathematics (n=60), Early Childhood Education (n=60), and Thai Language (n=58), totaling 178 pre-service teachers.
2. The sample was obtained through cluster random sampling and comprised 30 pre-service teachers majoring in Mathematics, specifically from Group 1, who were enrolled in the Curriculum Development and Teaching Methodology course in the second semester of the 2024 academic year.

3.1.2. Scope of Content and Variables Studied

1. The independent variable was the phenomenon-based learning management model integrating a digital learning ecosystem.
2. The dependent variables were: (1) Metacognition Learning Achievement; (2) Students' opinions towards the phenomenon-based learning management model integrating a digital learning ecosystem.

3.2. Research Instruments

The research instruments consisted of 1) these lesson plans were designed based on the phenomenon-based learning approach and integrated the principles of a digital learning ecosystem. They served as instructional materials for delivering the learning intervention to the pre-service teachers. 2) This test was developed to measure the metacognition learning achievement of the pre-service teachers after they participated in the learning activities guided by the phenomenon-based learning management plans. The test items were designed to align with the learning objectives related to metacognition. 3) This questionnaire was designed to gather feedback and opinions from the pre-service teachers regarding their experience with the phenomenon-based learning management model and its integration of the digital learning ecosystem. The questionnaire typically included items assessing various aspects such as the model's clarity, relevance, engagement, and perceived impact on their learning.

3.3. Development of Research Instruments

The researcher developed the learning management plans through the following steps:

1. The researcher conducted a data analysis on learning management by studying and analyzing concepts, theories, and research from documents and textbooks related to learning management approaches based on a digital learning ecosystem integration model. This step involved a review of relevant literature to establish a theoretical framework and evidence-based practices for the learning management plan design.
2. The researcher designed learning management plans for phenomenon-based learning, integrating a digital learning ecosystem. These plans comprised three main phases:

This phase focused on defining the desired learning outcomes and addressing the learners' needs in their educational experiences, consisting of two sub-activities:

This sub-activity involved specifying learning objectives related to knowledge acquisition and understanding.

This sub-activity focused on setting learning objectives concerning skills development and practical application.

This phase aimed to foster transformative learning experiences and included three sub-activities:

This involved the instructional design process, outlining the learning activities, materials, and sequence of instruction.

This sub-activity focused on incorporating phenomenon-based learning strategies into the lesson plan, using real-world phenomena as the context for learning.

This sub-activity integrated digital learning ecosystem principles to facilitate knowledge sharing, collaboration, and communication among learners.

This phase concentrated on the evaluation of learning outcomes and comprised two sub-activities:

This sub-activity involved assessing learning outcomes based on the knowledge system, focusing on factual and conceptual understanding. (This aligns with cognitive domain assessment).

This sub-activity focused on evaluating learning outcomes related to the metacognitive system, assessing learners' self-awareness of their thinking and learning processes.

3. Expert validation of learning management plans involved three experts examining the phenomenon-based learning management plans that integrate a digital learning ecosystem. The Index of Item-Objective Congruence (IOC) was analyzed, resulting in IOC values ranging from 0.67 to 1.00. This indicates an acceptable level of content validity for the learning management plans.
4. Revision of Learning Management Plans: The learning management plans were revised based on the recommendations and feedback provided by the experts to enhance clarity, accuracy, and instructional effectiveness.
5. Implementation of Learning Management Plans with the Sample Group: The revised learning management plans were implemented with the sample group for a duration of 12 weeks, with 3 hours per week, totaling 36 hours. This implementation phase allowed for the practical testing and application of the developed learning management plans in a real classroom setting.

3.4. Data Collection

The researcher implemented the data collection process as follows:

1. The researcher clarified the learning objectives of the phenomenon-based learning management model integrating a digital learning ecosystem to the pre-service teachers. This step ensured that the students were informed about the intended learning outcomes and the purpose of the learning activities.
2. A pretest was administered to the students prior to the commencement of the learning intervention. This pretest served as a baseline measure of their metacognition learning achievement before exposure to the phenomenon-based learning management model.
3. Learning was conducted using phenomenon-based learning management plans integrating a digital learning ecosystem. This involved the researcher acting as the instructor and guiding the pre-service teachers through the designed learning activities as outlined in the lesson plans over the specified duration.
4. Upon completion of the learning intervention, a posttest was administered to assess the students' metacognition learning achievement gains. Concurrently, a questionnaire was administered to gather students' opinions and feedback regarding their learning experiences with the phenomenon-based learning management model integrating a digital learning ecosystem.
5. The collected data, including learning achievement scores from the pretest and posttest, and students' responses from the opinion questionnaires, were analyzed. This involved both quantitative analysis of the

learning achievement data and qualitative analysis of the students' opinions to provide a comprehensive understanding of the research findings.

4. Results

The researcher presents the research findings in three main points, as follows:

1. The mean percentage score of metacognition learning achievement after learning through the phenomenon-based learning management model integrating a digital learning ecosystem was 80.25%. This indicates that, on average, students demonstrated a high level of metacognitive skills after participating in the learning intervention.
2. The analysis of learning gain indicated a medium level of normalized gain (<g> = 0.64). Furthermore, the comparison of metacognition learning achievement scores revealed that the post-test mean score was significantly higher than the pre-test mean score, with statistical significance at the 0.01 level ($p < 0.01$). This statistically significant difference suggests that the phenomenon-based learning management model had a positive impact on enhancing students' metacognition learning achievement.

Table 1. Comparison of pre-test and post-test scores on metacognition learning achievement.

	Test	n	Full score	X	S.D.	t-test (One-tailed)	p-value
Group	Pre-test	30	60	27.56	7.28	-36.37	<0.001*
	Post-test	30	60	48.56	6.35		

Note: * Statistically significant at the 0.01 level.

From Table 1, the mean score of post-test metacognition learning achievement (=48.56, S.D.=6.35) was found to be significantly higher than that of the pre-test (=27.56, S.D.=7.28), with statistical significance at the 0.01 level ($p < 0.01$).

The overall student opinion regarding the learning management model was positive, with agreement at a high level across all items. The aspect ranked highest was benefits, with students indicating that the model enhanced opportunities to practice curriculum development skills for their future teaching profession. They also gained approaches for developing learners to plan their own learning in ways that foster metacognition, and the model promoted self-directed learning, self-regulation, and goal attainment in learning. The next highest level of agreement was in the aspect of learning atmosphere. Students agreed that the model facilitated the presentation of curriculum development ideas to enhance metacognition, promoted self-directed learning planning in the Curriculum Development course to enhance metacognition, encouraged learning planning, and enabled the selection of learning resources from various facilities and knowledge sources, including the digital learning ecosystem, for curriculum development. Furthermore, the activities incorporated digital media and technologies that fostered independent learning. The model also provided guidance and utilized questions to help students apply learning processes to curriculum and instruction development. Finally, the activities provided knowledge about developing higher-order thinking skills and learning, respectively.

3. Students' opinions on the phenomenon-based learning management model integrating a digital learning ecosystem: students expressed a high level of agreement with the phenomenon-based learning management model integrating a digital learning ecosystem.

The overall student opinion indicated a high level of agreement. The aspect ranked first was benefits, with students agreeing that the model enhanced their digital skills and self-protection skills in the digital age, which could be applied to their real lives and future teaching careers. The next highest level of agreement was in the aspect of learning activities, with students agreeing that the model provided guidelines for learners to choose learning methods and search for knowledge from real-world educational settings and the digital learning ecosystem. Following this, students also expressed a high level of agreement with the learning atmosphere, stating that it fostered a friendly and supportive environment through the online social media of the learner group, which effectively met their needs in seeking research for curriculum development, respectively.

5. Discussion

The researcher discusses the findings based on the learning management model as follows. The entire three-step learning management process was designed using phenomenon-based learning, metacognitive learning concepts, and constructivism. A detailed discussion of the research findings is provided below.

5.1. Learning Planning

The learning planning phase commences with setting learning objectives. This step is related to clarifying learning, aligning with the concept of knowledge-construction learning where learners are self-directed (Osborne & Wittrock, 1983). This is consistent with constructivist learning management, where learners autonomously set learning goals and objectives, or learners and instructors collaboratively define learning objectives (Murphy, 1997). Similarly, in setting learning objectives, learners must clearly understand what goals or skills they will achieve upon completion of the learning process (Marzano, 2007).

5.2. Developing Transformative Learning

This phase of transformative learning comprises three sub-activities: 2.1) Learning Design or Strategy Selection in the Digital Age. This involves designing learning experiences and choosing appropriate strategies suitable for the digital age learning environment; 2.2) Developing Transformative Learning Skills through Observation, Self-Regulation, and Plan Modification. This focuses on fostering transformative learning skills by encouraging observation, self-regulation according to learning plans to achieve goals, and adaptation of learning plans as needed; and 2.3) Knowledge Exchange via Digital Learning Ecosystem. This involves developing learning skills and seeking and utilizing learning resources through a digital learning ecosystem. As Bel and Mallet (2006) summarized, developing action learning activities requires instructional design that integrates teaching and technology, grounded in constructivism. Therefore, educational institutions need to establish guidelines for

learning management that emphasize diverse learning approaches tailored to the problems, interests, and needs of learners, both individually and in groups. Organizing learning activities should continuously emphasize the use of digital media and the development of various digital skills. In developing learning skills, instructors must incorporate digital technologies as part of the learning environment to promote active learning, which aligns with the Science-Students-Concepts-Society (SSCS) Model of Pizzini (1989) This model comprises four phases: 1) Search: identifying the problem and analyzing its causes; 2) Solve: problem-solving or finding answers to the identified problem; 3) Create: processing information obtained from problem-solving or answers into a structured response; and 4) Share: learners expressing their opinions about their own solutions and those of others. Knowledge integration focuses on facilitating deep learning among students through small group learning in a cooperative learning format, which helps develop social skills and teamwork behaviors. Johnson, Johnson, and Holubec (1994) stated that cooperative learning in any classroom lesson at any level can be structured cooperatively. A typical class session may involve grouping students into base groups, short lectures or group projects, and base group meetings as the final step. At the end of the lesson, learners reconvene in their base groups to summarize and synthesize what they have learned. This structure keeps learners alert and intellectually engaged in the task and focused on regular classroom learning.

5.3. Learning Assessment

This phase of learning assessment comprises two sub-activities: 3.1) Knowledge System Assessment (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956). This sub-activity focuses on assessing learning based on the knowledge system and 3.2) Metacognitive System Assessment (Marzano, 2007). This sub-activity focuses on assessing learning based on the metacognitive system. Knowledge system assessment involves retrospection and review. Metacognitive system assessment at this stage evaluates knowledge by connecting ideas between learning objectives and skills/practice. This is a knowledge and practical skill assessment based on the SOLO Taxonomy, which allows learners to self-monitor and review their achievement of learning outcomes and practical skills. Research by Brabrand and Dahl (2009) found that using the SOLO taxonomy is a valuable tool for analyzing the development of student abilities in university science courses. This aligns with Friedman, Cox, and Maher (2010), who found that setting assessment goals collaboratively motivates team members in grading and promotes teamwork. Goal setting is based on peer assistance in providing feedback and benchmarks for certain activities. This further enhances student motivation and responsibility.

After students received their learning results, the researcher conducted a follow-up inquiry. The findings are as follows.

Our group believes that the "Phenomenon-Based Learning Management Model Integrating a Digital Learning Ecosystem to Enhance Metacognition" is valuable because it significantly enhances the knowledge and skills of pre-service teachers, moving beyond traditional cognitive learning. We defined metacognition as the ability to think about one's own thinking, which includes planning, monitoring, evaluating, and adjusting learning strategies to achieve goals. This approach is a key pathway for successful pre-service teacher development.

To confirm this, a female student group commented that developing oneself through metacognitive processes is not just for personal growth; it can also be used to develop other learners. They outlined the key steps: awareness (knowing what you are thinking and your weaknesses), planning (setting goals and strategies), monitoring (tracking progress), evaluation (assessing outcomes and learning from mistakes), and adjustment (adapting strategies).

The students' comments highlight the core components of metacognition as defined by Flavell (1979), including planning, monitoring, evaluating, and adjusting. Their reflections suggest that the PhBL model, integrated with a DLE, not only facilitated the acquisition of factual knowledge but also fostered a deeper level of self-awareness and self-regulated learning, which are critical for effective teaching (Schraw & Dennison, 1994). This aligns with the findings of Fono and Zohar (2024), which emphasize the role of metacognition in professional development, particularly for pre-service teachers.

They concluded that metacognition is crucial for students to become high-quality individuals with the knowledge and skills required by the Teachers Council of Thailand. This thought process is highly beneficial for their future careers.

6. Recommendations

Based on the findings of this research, the following recommendations are proposed.

1. Effective implementation strategies for the learning management model: For effective implementation of the learning management model from this research, instructors should thoroughly examine the information regarding learning activity organization to ensure alignment with the proposed steps. It is crucial to utilize a learning ecosystem that fosters active learning and cultivates an atmosphere of self-discipline (Felder & Brent, 2009). Furthermore, leveraging online social networks to facilitate interaction between instructors and learners, as well as among learners themselves, is recommended. Emphasis should be placed on developing digital skills among learners. This comprehensive approach ensures that the learning environment is conducive to achieving the intended learning outcomes and maximizing the benefits of the phenomenon-based learning management model.
2. Institutional support and digital transformation for teacher education: The implementation of phenomenon-based learning management integrated with a digital learning ecosystem for pre-service teachers at the Faculty of Education, Nakhon Phanom University, represents a paradigm shift in educational management for Thai students. Therefore, it is imperative to develop a platform to serve as a mechanism for driving and supporting the transformation into a digital university (Siemens, 2005). Further research is needed to explore relevant systems, components, and indicators to guide this digital transformation in a way that promotes wisdom and aligns with the socio-economic context of Thailand. This includes investigating the infrastructural, pedagogical, and policy changes necessary to fully support digital learning initiatives and ensure equitable access and effective integration of digital technologies in teacher education.

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