Journal of Education, Prince of Songkla University, Pattani Campus
Vol.36 No.3 September – December 2025, pp. 119-129

Research Article

The Digital Learning Ecosystem Model to Enhance Digital Literacy Skills of Learners in the Education Sandbox, Chiang Mai Province

Janejira Arsarkij*
Ed.D. (Educational Technology), Lecturer
Educational Technology Program, Faculty of Education, Chiang Mai University
*Corresponding author: janejira.a@cmu.ac.th

Received: June 22, 2025/ **Revised:** December 26, 2025/ **Accepted:** December 29, 2025

Abstract

This Research and Development (R&D) study aimed to: 1) analyze the existing learning ecosystem in Education Sandbox, Chiang Mai Province; 2) develop a digital learning ecosystem model to enhance digital literacy of students in the area; and 3) evaluate the effectiveness of the learning ecosystem model and improve students' digital literacy. The study was conducted in three phases: exploration, development, and implementation. The participants consisted of 129 stakeholders involved in a needs assessment, 10 experts to validate model development, and 258 school students participating in digital literacy enhancement.

The research findings revealed: Phase 1) An analysis of the existing learning ecosystem across five dimensions including people, content, process, technology and learning culture. There was a significant differene between the current state which the mean ranged from 3.62 – 3.93, whereas the mean of stakeholders' expectations ranged from 4.37 – 4.49. The priority needs were identified in the "Content" component (PNI_modified = 0.207), followed by "Technology" (PNI_modified = 0.188), particularly regarding artificial intelligence content, and increasing access to digital technology resources and devices. Phase 2) The developed Digital Learning Ecosystem Model comprised five key steps: (1) Policy and Vision Setting, (2) Preparation, (3) Technology Implementation, (4) Cultivating Learning Culture, and (5) Evaluation and Improvement. The model was evaluated by experts as having a very high level of appropriateness (Mean = 4.65, S.D. = 0.49). Phase 3) The learning ecosystem model was implemented according to the proposed plan, aiming to build a learning culture, to enhance digital technology integration for teachers, and to provide the knowledge of digital technology for learners. Students' digital literacy skills significantly improved after using the model, with the mean score increasing from 2.94 (pre-test) to 3.73 (post-test) at the .05 significance level. The most notable improvements were observed in practical skills and collaborative skills. Furthermore, stakeholders expressed high satisfaction with the model, noting its effectiveness in building confidence and fostering a sustainable digital learning culture. It is recommended that schools, especially in Education Sandbox areas or underserved regions, adopt this model to systematically strengthen digital literacy. Emphasis should also be placed on ongoing teacher development, technology investment, and stakeholder collaboration to ensure sustainability.

Keywords: Learning Ecosystem, Digital Learning Ecosystem, Digital Literacy Skills, Education Sandbox

Introduction

Digital literacy competency has become an essential skill in the 21st century, allowing individuals to effectively navigate and contribute to the modern digital society (National Science and Technology Development Agency, 2020; Centre for Strategic and International Studies, 2024). Since digital technology continues to transform education, workplaces, and daily life, digital literacy plays and an important role as a foundation for lifelong learning and adaptability (Atchoarena et al., 2021; Fowler, 2023; Reddy et al., 2023). However, access to quality digital devices and education remains unequal, especially in rural and remote areas, where resources, infrastructure, and training are often inadequate. In Thailand, rapid digitalization has highlighted a significant digital divide. While urban areas benefit from better access to technology, rural areas confront persistent challenges, including limited internet connectivity, a lack of digital devices, and insufficient training for educators. These issues create critical barriers, preventing rural learners from participating equally in digital opportunities.

Chiang Mai Province was one of the education sandbox initiative project, particularly in Fang District, representing a strategic approach to addressing these challenges (Edu Sandbox, 2023). Fang District is characterized by its diverse socio-economic landscape, blending urban and rural elements, which makes it an ideal testing ground for scalable educational interventions. As a designated area for piloting innovative educational practices, the Education Sandbox provides a unique opportunity to experiment with and refine models for enhancing digital literacy (Limsuwannarot et al., 2023).

Prior to the intervention, a preliminary survey revealed that the digital learning ecosystem within the target schools lacked systematic planning and management. This issue was further exacerbated by the inadequate of academic literature and research specifically addressing digital learning ecosystems in the Thai context, leaving educators with limited guidance. Learners were thus deprived of appropriate and modern knowledge organization essential for their development. To address these systemic gaps, the community-based research approach was employed in order to gather in-depth insights from local people. Engaging the community is crucial for clearly reflecting the current state of the locality and identifying their specific needs and aspirations regarding how the digital learning ecosystem should be managed. This approach prioritized active community participation, based on the premise that community members possess the deepest understanding of their own context.

To provide a theoretical framework for this initiative, the concept of a "Learning Ecosystem" has emerged as a holistic framework for addressing educational challenges. Unlike traditional isolated learning methods, a learning ecosystem emphasizes the dynamic interconnections between learners, educators, content, and technologies within a specific environment (Global Education Futures, 2020; OECD, 2020). When applied to the digital domain, a Digital Learning Ecosystem integrated diverse digital tools and platforms to facilitate flexible, personalized, and collaborative learning experiences (Belessova et al., 2023). Some previous studies have indicated that a well-structured ecosystem significantly enhances students' digital competencies by fostering an environment where access to technology is seamless and supported by a strong learning culture (Chuenchom et al., 2021; Pinto-Llorente et al., 2024).

This research aimed to bridge the digital literacy gap in rural education by developing a context-specific Digital Learning Ecosystem model for the Education Sandbox in Chiang Mai Province. The model integrated key local components: schools, families, and communities with digital technology to enhance access and learning outcomes, aligning with Sustainable Development Goal 4 (SDG 4). Furthermore, this study contributes to the literature on educational innovation by providing a practical framework for co-creating solutions that are both effective and sustainable. By developing and evaluating a model tailored to the needs of stakeholders, this research intends to provide actionable insights for narrowing educational disparities in the digital era.

Research Objective

1. To study and analyze the current learning ecosystem in the education sandbox Chiang Mai Province.
2. To develop a digital learning ecosystem model that effectively enhances digital literacy skills of learners in education sandbox.
3. To improve the digital literacy skills of students and evaluate the implementation of the developed model.

Research Framework

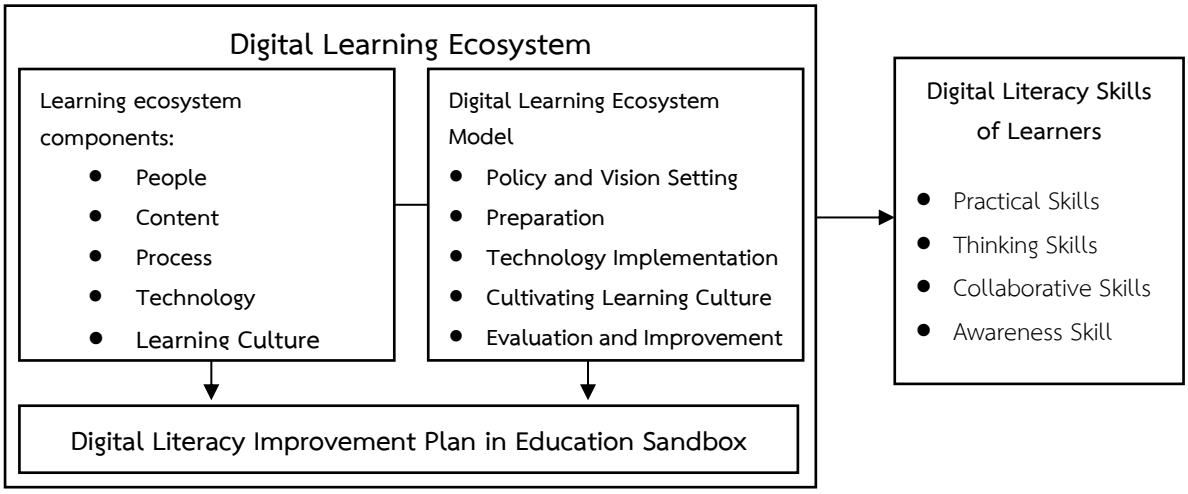
The research conceptual framework in this research comprised some vital theories consisting of: learning ecosystem components which had to be considered as a part of phase one data collection; digital learning ecosystem model, digital literacy skills.

The Successive Approximation Model (SAM) as the guiding instructional design process. It consists of three main parts corresponding to the Research and Development (R&D) phases: 1) This included the five key components of a learning ecosystem: People, Content, Process, Technology, and Learning Culture, which served as the framework for the needs assessment in Phase 1. 2) This stage focuses on the design and development of the Digital Learning Ecosystem Model driven by the Successive Approximation Model (SAM). This iterative approach was employed to systematically construct and refine the model, ensuring it effectively integrates local community contexts with digital technology to support learning management in the Education Sandbox. 3) The key outcome is the enhancement of learners' Digital Literacy Skills, comprising practical skills, thinking skills, collaborative skills, and awareness skills.

The developed research conceptual framework is illustrated in Figure 1.

Figure 1

Research conceptual framework



This study utilized a Research and Development (R&D) methodology, structured into three phases: 1) Needs Assessment, 2) Model Development, and 3) Model Implementation.

Phase 1: Exploration and Needs Assessment

Research Design: This phase involved assessing the current state of the learning ecosystem and identifying needs through surveys and focus group discussions.

Population and Sample: The population consisted of stakeholders in the Education Sandbox, Fang District, Chiang Mai Province.

The sample comprised 128 participants: school administrators, teachers, students, and community representatives, for the survey, and 30 key informants for the focus group discussions.

Sampling Method: Purposive sampling was employed.

Justification: The sample was selected based on their direct involvement and role in the Education Sandbox project to ensure the data reflected the actual context and needs of the area.

Data Analysis: Data were collected using questionnaires and analyzed using descriptive statistics (Mean, S.D.) and Priority Needs Index (PNI_modified). Qualitative data from focus groups were analyzed using content analysis.

Phase 2: Model Development

Research Design: This phase focused on designing and refining the prototype of the Digital Learning Ecosystem Model.

Population and Sample: The key informants were 10 experts specializing in educational technology, learning ecosystems, and curriculum design.

Sampling Method: Purposive sampling.

Justification: Experts were selected based on their specific qualifications, possessing at least five years of experience in their respective fields, to ensure the validity and quality of the developed model.

Data Analysis: The model was evaluated using an evaluation form. The data were analyzed using Mean and Standard Deviation to assess the suitability of the model components.

Phase 3: Model Implementation

Research Design: The developed model was implemented in pilot schools to evaluate its effectiveness in enhancing digital literacy skills.

Population and Sample: The population consisted of 1,577 secondary school students from six schools in the Education Sandbox, Fang District.

The sample consisted of 258 students.

Sampling Method: Purposive sampling was initially used to select the participating schools, followed by purposive sampling of students within the target level.

Justification: Two schools were selected based on the criteria of *readiness and willingness* to participate in the full implementation process. The sample size was determined based on the criterion of 10–15% of the population (1,577 x 15% = approx. 237), making the sample of 258 students sufficient for the study. Additionally, simple random sampling was used to select 10 students from each school for focus group interviews to provide in-depth feedback.

Data Analysis: Data were collected using the Digital Literacy Assessment Tool (pre-test and post-test) and satisfaction surveys. Data were analyzed using dependent t-tests to compare scores before and after implementation.

Research Instruments

The research instruments used in this study were examined for quality by three experts in educational technology and measurement. Based on the experts' suggestions, the instruments were revised, and the validity values were calculated. The details of each instrument and its quality validation are as follows:

1. Questionnaire on Current State and Needs was designed to collect data regarding stakeholder perceptions of the current learning ecosystem and their expectations. It consisted of 30 items using checklist and Likert-scale formats. The content validity was verified by experts, yielding an Index of Item-Objective Congruence (IOC) ranging from 0.67 to 1.00. The reliability of the questionnaire was tested with a try-out group, resulting in a Cronbach's alpha coefficient of [0.87], indicating high reliability.

2. Semi-structured Interview Questions was used to gather in-depth information about challenges and needs through focus group discussions. It comprised 10 open-ended questions covering the learning environment, digital tools usage, and skill development. The questions were validated by experts for clarity and relevance, with IOC values ranging from 0.67 to 1.00.

3. Digital Learning Ecosystem Model Evaluation Form: This form was used by experts to evaluate the suitability of the developed Digital Learning Ecosystem Model components (People, Content, Process, Technology, and Learning Culture). It consisted of 20 items. The items were validated for content validity, with IOC values ranging from 0.67 to 1.00.

4. Digital Literacy Assessment Tool was adapted from Chuenchom et al. (2021) to evaluate students' digital literacy skills before and after implementation. It comprised 30 items assessing practical, thinking, collaborative, and awareness skills. The content validity was verified by experts (IOC = 0.67–1.00). The reliability was tested, yielding a Cronbach's alpha coefficient of [0.85].

5 . Semi-structured Interview Guide (Feedback) was used to collect feedback on the usability and effectiveness of the model. It consisted of 10 questions. The questions were reviewed by experts to ensure language appropriateness and content validity (IOC = 0.67–1.00).

Data Collection Procedure

The data collection followed the three phases of the R&D process. In Phase 1, questionnaires were distributed to stakeholders, followed by focus group discussions. In Phase 2, the draft model was presented to ten experts for evaluation and refinement. Then the digital learning ecosystem was structured regarding results from phase one and the suggestions and recommendation from experts. In Phase 3, workshops were organized for teachers, followed by the implementation of the model with students. Pre-test and post-test assessments were conducted, and post-implementation interviews were held to gather feedback.

Ethical Considerations

Approval for exemption from full ethical review was granted by the Human Research Ethics Committee of Chiang Mai University. This research adhered to ethical guidelines for studies involving human participants. Generative AI tools (OpenAI, 2025; Google, 2025) were utilized for grammatical checking and language editing of the manuscript.

Results

The results of this study are presented in three parts, corresponding to the research objectives and the R&D phases: Part 1 presents the analysis of the current state and needs regarding the digital learning ecosystem (Phase 1); Part 2 describes the development and quality evaluation of the digital learning ecosystem model (Phase 2); and Part 3 reports the results of implementing the model on learners' digital literacy skills and stakeholder feedback (Phase 3).

Phase 1: The Condition and Needs of the Digital Learning Ecosystem

The analysis of the current state and stakeholder expectations focused on five key components: People, Content, Process, Technology, and Learning Culture. These quantitative findings were corroborated by qualitative data from interviews and focus group discussions, as summarized in Table 1.

Table 1

The current learning ecosystem and expectation of stakeholders

	Current Situation (D)		Expected Situation (I)		Needs(I-D/D)	Degree of
Details of Items	Mean	S.D.	Mean	S.D.	PNI $_{modified}$	importance
People	3.86	0.56	4.44	0.75	0.150	4
Content	3.62	.059	4.37	0.78	0.207	1
Process	3.93	0.65	4.46	0.75	0.135	5
Technology	3.73	0.63	4.43	0.75	0.188	2
Learning Culture	3.81	0.54	4.49	0.72	0.178	3
Overall	3.79	0.59	4.45	0.75	0.174	

The findings revealed significant gaps between the current state and expectations, highlighting areas needing urgent improvement. There was a significant difference between the current state (Mean = 3.62–3.93) and stakeholders' expectations (Mean = 4.37–4.49). The Modified Priority Needs Index (PNI_modified) results indicated that "Content" (specifically learning and professional development content) required the most improvement (PNI_modified = 0.207), followed by "Technology" (PNI_modified = 0.188) and "Learning Culture" (PNI_modified = 0.178).

To provide a deeper understanding of these gaps, qualitative data gathered through interviews and focus group discussions were analyzed. The specific insights regarding the current state and challenges for each ecosystem component are detailed in Table 2.

Table 2

The summary of content analysis from the interviews and focus group discussion

Component	Current State and Identified Challenges
People	Administrators highlighted the need for a consistent professional development plan within school policies. While some teachers expressed moderate confidence in using digital tools, most students showed varying digital literacy levels, with notable weaknesses in utilizing advanced applications such as AR/VR tools.
Content	Digital learning materials were found to be lacking. Approximately 70% of teachers reported difficulties in implementing new digital technology content in their classes.
Process	The processes and methods for delivering digital technology knowledge were limited. Online collaborative learning activities were utilized infrequently. Traditional teacher-centered methods remained the primary pedagogy employed in classrooms.
Technology	Limited internet access and insufficient devices were identified as major barriers to learning activities. Over 60% of respondents highlighted infrastructure challenges in their schools. The need for open-access, tailored digital content was strongly emphasized by all stakeholders.
Learning Culture	While schools were gradually integrating technology, a digital learning culture had not yet been fully established. Furthermore, parent and community involvement in learning activities remained low.

The content analysis in Table 2 corroborates the quantitative findings, underscoring critical barriers such as the lack of up-to-date digital content (especially AI), insufficient infrastructure, and the need for a stronger digital learning culture. These insights served as the foundation for planning teacher training support and crafting the Digital Learning Ecosystem Model in the next phase.

Phase 2: The Development of the Digital Learning Ecosystem Model

Based on the needs assessment in Phase 1, the Digital Learning Ecosystem Model was developed. The model comprised five key implementation steps: 1) Policy and Vision Setting, 2) Preparation of resources and training, 3) Technology Implementation, 4) Cultivating Learning Culture, and (5) Evaluation and Improvement.

The quality of the developed model was evaluated by ten experts. The evaluation covered standard criteria and implementation appropriateness.

Table 3

The results from experts' evaluation of the standard of evaluation learning ecosystem model (Joint Committee on Standard for Education Evaluation, 2020)

Areas of assessment	Mean	S.D.	Level of quality
Utility Standards	4.80	0.40	Very high
Feasibility Standards	4.70	0.50	Very high
Propriety Standards	4.60	0.52	Very high
Accuracy Standards	4.67	0.46	Very high
Evaluation Accountability Standards	4.47	0.55	Very high
Overall	4.65	0.49	Very high

Appropriateness Evaluation: As shown in Table 3, the experts agreed that the model was highly appropriate for implementation (Overall Mean = 4.65, S.D. = 0.45). The Standard Evaluation areas comprised utility standards (4. 80), feasibility standards (4. 70), propriety standards (4. 60), accuracy standards (4. 67), and Evaluation Accountability Standards (4.47). The experts suggested that clear explanations for each process and collaboration with families were essential for sustainability.

Table 4

The results experts' evaluation of the implementation appropriation of the learning ecosystem model

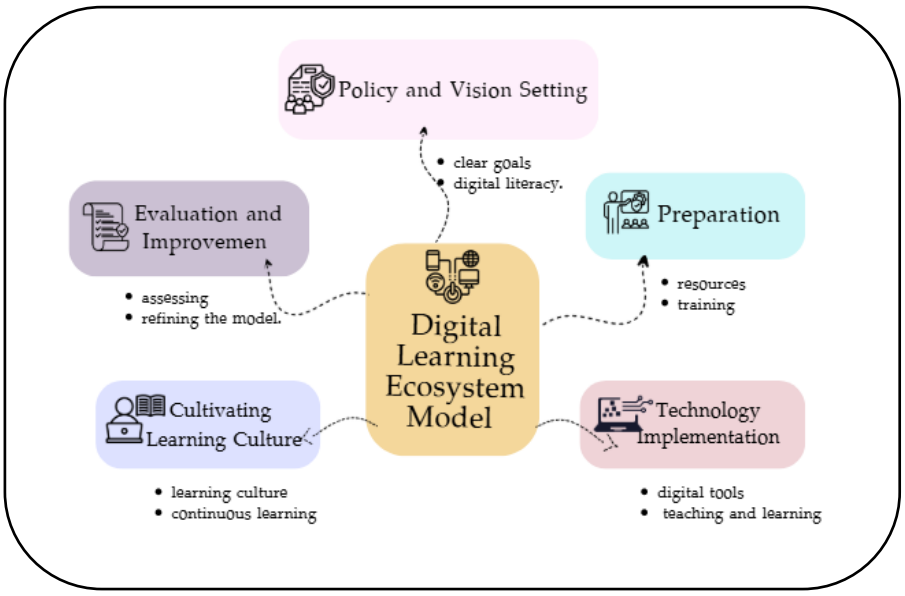
Areas of assessment	Mean	S.D.	Level of quality
Design and structure of model	4.67	0.51	Very high
Content quality	4.73	0.48	Very high
Technologies and tools implantation	4.73	0.33	Very high
Teaching and learning supports	4.53	0.55	Very high
Overall effectiveness and satisfaction	4.67	0.37	Very high
Evaluation, improvement and development	4.57	0.45	Very high
Overall	4.65	0.45	Very high

The process of the learning ecosystem model included design and structure of model content quality, technologies and tools implantation, teaching and learning supports, overall effectiveness and satisfaction, and Evaluation, improvement and development. It was demonstrated that the experts agreed that the overall learning ecosystem model was very high level of appropriate, with an overall score of 4.65.

Moreover, content analysis and suggestions from experts included the clearer explanation for each process, emerging digital technologies should always be considered as improvement plan, and the collaboration with families and communities to enhance engagement and sustainability. The Digital Learning Ecosystem Model was developed regarding the experts' recommendation displayed in Figure 2.

Figure 2

Digital Learning Ecosystem Model for Implementation



The Infographic illustrates the development of digital learning ecosystem implementation steps comprised:

1. Policy and Vision Setting: the policy should be determined the clear goals for fostering digital literacy.

2. Preparation: the preparation of both necessary resources and customized training.

3. Technology Implementation: the integration of digital technologies into teaching and learning.

4. Cultivating Learning Culture: the learning culture that supports continuous learning. Evaluation and Improvement: the assessment should be regularly conducted and refining the model.

Phase 3: Results of Model Implementation

The results of implementing the model in the Education Sandbox are presented in two aspects: quantitative student outcomes and qualitative ecosystem evaluation.

1) Digital Literacy Skills Improvement

Quantitative analysis using paired samples t-tests compared students' digital literacy skills before and after using the ecosystem model.

Table 5

Comparison of students' digital literacy skills before and after implementation

Digital Literacy	N	The Mean and Standard Deviation				t	p
		Before		After			
		Mean	S.D.	Mean	S.D.		
Practical Skills	258	2.76	0.78	3.77	0.74	16.598	.000
Thinking Skills	258	3.04	0.92	3.66	0.76	9.338	.000
Collaborative Skills	258	3.19	0.92	3.84	0.77	9.140	.000
Awareness Skill	258	2.96	0.79	3.65	0.76	11.025	.000
Average		2.94	0.75	3.73	0.73		

**Statistically significant at the .05 level*

As shown in Table 5, a comparison of the students' overall digital literacy skills before and after the intervention revealed a statistically significant difference at the .05 level. The overall mean score increased from 2.94 at the pre-test to 3.73 at the post-test. When analyzing specific domains, significant improvements were observed across all factors ($p < .05$). Collaborative skills showed the highest post-test score, increasing from 3.19 to 3.84, followed by practical skills (2.76 to 3.77), thinking skills (3.04 to 3.66), and awareness skills (2.96 to 3.65).

2) Evaluation of the Ecosystem Implementation

Focus group discussions highlighted high satisfaction among participants, who noted that the training was practical and increased their confidence. However, to further improve the ecosystem, stakeholders suggested five key areas for development:

1. Infrastructure: While smart classrooms were established, there is a need to increase the number of devices to ensure accessibility for all students and upgrade to high-speed internet to support seamless online learning.

2. Pedagogy and Technology Integration: Current integration is limited to specific courses using basic LMS (e.g., Google Classroom). Future implementation should incorporate emerging technologies (AI, AR/VR) and blended learning approaches to deepen learning experiences.

3. Teacher Development: Teachers require specialized training in AI literacy, cybersecurity, and digital pedagogy, supported by a Professional Learning Community (PLC) for knowledge sharing.

4. Partnerships: Expanding collaboration with universities and the private sector could provide students with internships and opportunities to participate in digital competitions, such as Hackathons.

5. Digital Culture: Initiatives should shift focus from passive consumption to fostering "Digital Citizenship," emphasizing responsible use and student-generated content.

Discussions

The findings of this research can be discussed according to the research objectives as follows:

1. The State and Needs of the Learning Ecosystem

The study revealed that the current learning ecosystem in the Education Sandbox had significant gaps, particularly in "Learning Culture" and "Digital Content." This finding aligns with Sociocultural Theory, which emphasizes that learning is a social process deeply influenced by the environment and cultural context. The results are consistent with the study of Limsuwannarot et al. (2023), who found that successful educational innovation in sandbox areas required not just infrastructure, but a supportive culture and active participation from stakeholders. Furthermore, the identified need for integrated digital resources supported the concept of a learning ecosystem proposed by Setthawatbodee et al. (2023) and Saiyaporn (2022), which posited that the seamless connection between technology and content was essential for effective learning environments. This is also in agreement with the Office of the Education Council (2021), which indicated that a suitable learning ecosystem for Thailand must prioritize context-specific conditions to effectively drive educational quality.

2. The Development of the Digital Learning Ecosystem Model

The developed model comprised five key components: Policy, Preparation, Technology, Learning Culture, and Evaluation. This structure was consistent with the "Learning Ecosystem" framework described by Global Education Futures (2020) and OECD (2020), which advocated for a holistic approach connecting learners, educators, and community resources. The high appropriateness scores from experts (Mean = 4.65) indicated that the model effectively integrated these elements. This finding supported the work of Belessova et al. (2023) and Maneehaet & Wannapiroon (2019), who stated that a well-structured digital ecosystem must facilitate flexible and personalized learning experiences rather than merely providing hardware. Additionally, the model's focus on teacher preparation and lifelong learning mechanisms aligns with Atchoarena et al. (2021) and the global standards of the European Commission (2019), ensuring that educators are equipped to facilitate digital competencies effectively within a learning society.

3. The Effectiveness of the Model on Digital Literacy Skills

Post-implementation results showed a significant improvement in students' digital literacy skills ($t = 16.598$, $p < .05$), particularly in "Practical Skills" and "Collaborative Skills." This result was consistent with the findings of Chuenchom et al. (2021); Pinto-Llorente et al. (2024); and Nguyen et al. (2023), who demonstrated that an integrated digital learning environment significantly enhances students' ability to use digital tools for online collaboration and inquiry. The findings also validated the Digital Literacy Global Framework (UNESCO, 2021), demonstrating that when learners interact within a supportive ecosystem, facilitated by teacher training and peer collaboration, their competencies in critical thinking and digital awareness are significantly developed. Furthermore, the improvement in all dimensions aligns with Yuangsoi & Wannakhao (2023), Reddy et al. (2023), and Fowler (2023), who emphasized that digital literacy is a crucial foundation for adaptability and lifelong learning in the modern digital society.

Recommendations

1. Recommendations for Implementation

1.1 The initial data collection process is crucial for gathering in-depth insights to design a context-specific Digital Learning Ecosystem. Understanding the specific needs of the locality ensures that the developed ecosystem effectively supports stakeholders.

1.2 To successfully implement the Digital Learning Ecosystem, preparing the readiness of teachers and learners regarding digital literacy is essential. Furthermore, the preparation of physical infrastructure and digital devices is vital to support workshops and training activities within the ecosystem.

2. Recommendations for Future Studies

2.1 Future research should apply the Digital Learning Ecosystem model to broader areas or diverse demographics. Investigating and comparing the model's effectiveness across different levels of students could reveal correlations between learner characteristics and digital literacy skills within the ecosystem.

2.2 Long-term research should be conducted to assess the sustainability and impact of the Digital Learning Ecosystem model. Longitudinal studies would provide valuable insights into how the ecosystem influences the evolution of digital literacy skills and learning outcomes over time.

Acknowledgements

I would like to extend my deepest gratitude to Chiang Mai University for this research funding. I am also immensely grateful to all experts for their invaluable and insightful and constructive suggestions throughout the planning and development of this research. My sincere thanks go to all of administrators at Fang District, teachers and students from the pilot schools who collaborated, coordinated and participated in this project. Additionally, OpenAI's ChatGPT (March 2025 version) and Google's Gemini were utilized for language refinement and grammatical checks in this manuscript.

References

Atchoarena, D., & Howells, A. (2021). Advancing learning cities: Lifelong learning and the creation of a learning society. In S. Ra, S. Jagannathan, & R. Maclean (Eds.), *Powering a learning society during an age of disruption* (Vol. 58, pp. 165–180). Springer. https://doi.org/10.1007/978-981-16-0983-1_12

Belessova, D., Ibashova, A., Bosova, L., & Shaimerdenova, G. (2023). Digital learning ecosystem: Current state, prospects, and hurdles. *Open Education Studies, 5*(1), 20220179. https://doi.org/10.1515/edu-2022-0179

Centre for Strategic and International Studies. (2024). *The digital literacy imperative*. CSIS. https://www.csis.org/analysis/digital-literacy-imperative

Chuenchom, S., Jairak, K., & Kowan, U. (2021). Digital literacy skill development of Chiang Mai Rajabhat University students for improving learning quality. *Journal of Information Science, 39*(2), 1–20. https://doi.org/10.14456/jiskku.2021.8 [in Thai]

EduSandbox. (2023). *InnoSchool overview*. https://www.edusandbox.com/innoschool-overview/

European Commission. (2019). *Key competences for lifelong learning*. Publications Office of the European Union. https://data.europa.eu/doi/10.2766/569540

Fowler, G. (2023). *The importance of digital literacy in the modern world*. GSD Ventures. https://www.gsdvs.com/post/the-importance-of-digital-literacy-in-the-modern-world

Global Education Futures. (2020). *Learning ecosystems: An emerging praxis for the future of education*. Global Education Futures & Moscow School of Management SKOLKOVO. https://inee.org/sites/default/files/resources/LA_eng_1.pdf

Google. (2025). *Gemini* [Large language model]. https://gemini.google.com

Juicharern, A. (2019). *Learning ecosystem*. Posttoday. https://www.posttoday.com/economy/news/578269 [in Thai]

Kharas, H., McArthur, J. W., & Dooley, C. (2022). *The digital literacy imperative*. Center for Strategic & International Studies. https://www.csis.org/analysis/digital-literacy-imperative

Limsuwannarot, O., Chanma, C., & Jarujittipan, P. (2023). Developmental guidelines to be an educational innovative organization for the basic schools in the Education Sandbox of Thailand. *Asia Social Issues, 17*(3), e254720. https://doi.org/10.48048/asi.2024.254720 [in Thai]

Maneehaet, S., & Wannapiroon, P. (2019). A digital learning ecosystem with artificial intelligence for smart learning. *Journal of Education and Innovation, 21*(2), 359–373. https://so06.tci-thaijo.org/index.php/edujournal_nu/article/view/159123 [in Thai]

National Science and Technology Development Agency. (2020). *Digital literacy*. https://www.nstda.or.th/th/nstda-knowledge/142-knowledges/2632 [in Thai]

Nguyen, L. T., Kanjug, I., Lowatcharin, G., Manakul, T., Poonpon, K., Sarakorn, W., Somabut, A., Srisawasdi, N., Traiyarach, S., & Tuamsuk, K. (2023). Digital learning ecosystem for classroom teaching in Thailand high schools. *Sage Open, 13*(1). https://doi.org/10.1177/21582440231158303

Nielsen, R., Llorente, I., Virtanen, J., & Guillen, J. (Eds.). (2025). *The 2024 aquaculture economic report*. Publications Office of the European Union. https://data.europa.eu/doi/10.2760/5049952

OECD. (2020). *Innovative learning environments: A framework for education sandboxes*. Organisation for Economic Co-operation and Development. https://www.oecd.org/education

OECD. (2023). *Digital skills and digital inclusion*. Organisation for Economic Co-operation and Development. https://www.oecd.org/content/dam/oecd/en/about/projects/cfe/oecd-city-network-on-jobs-and-skills/Briefing-note-Digital-skills-and-digital-inclusion.pdf

Office of the Education Council, Ministry of Education. (2021). *Conditions for arranging a learning ecosystem suitable for the context of Thailand*. S.B.K. Printing. [in Thai]

OpenAI. (2025). *ChatGPT (Mar 2025 version) [Large language model].* https://openai.com

Pinto-Llorente, A. M., & Izquierdo-Álvarez, V. (2024). Digital learning ecosystem to enhance formative assessment in second language acquisition in higher education. *Sustainability, 16*(11), 4687. https://doi.org/10.3390/su16114687

Reddy, P., Chaudhary, K., & Hussein, S. (2023). A digital literacy model to narrow the digital literacy skills gap. *Heliyon, 9*(3), e14878. https://doi.org/10.1016/j.heliyon.2023.e14878

Saiyaporn, A. (2022). Creating a learning ecosystem...towards developing learners as lifelong learners. *Educathai*. https://www.educathai.com/knowledge/articles/586 [in Thai]

Setthawatbodee, S., Klangphahol, K., Ju-ngam, B., Phadungsilp, P., & Sawasdee, A. (2023). The study of learning ecosystem of educational institutions in Pathum Thani Province. *Education Journal Faculty of Education, Nakhon Sawan Rajabhat University, 6*(1), 102–113. https://so02.tci-thaijo.org/index.php/edunsrujo/article/view/258633 [in Thai]

Theodotou, M. (2020). *Learning ecosystem: Why you need one, how to build it*. Association for Talent Development. https://www.td.org/insights/learning-ecosystem-why-you-need-one-now-and-how-to-build-it

UNESCO. (2021). *Digital literacy global framework (DLGF)*. United Nations Educational, Scientific and Cultural Organization. https://unesco.org/digital-literacy-framework

UNICEF Office of Global Insight and Policy. (2020). *Digital literacy: Scoping review*. UNICEF. https://www.unicef.org/innocenti/media/1216/file/%20UNICEF-Global-Insight-digital-literacy-scoping-paper-2020.pdf

Wongwanich, S. (2015). *Needs assessment research*. (3rd ed.). Chulalongkorn University Book Centre. [in Thai]

Yuangsoi, P., & Wannakhao, C. (2023). Digital literacy skills for learning in the new normal. *Journal of Graduate School Sakon Nakhon Rajabhat University, 20*(91), 1–10. [in Thai]