Journal of Infrastructure, Policy and Development 2024, 8(8), 4415.
https://doi.org/10.24294/jipd.v8i8.4415

Article

Digital literacy and fluency in education: Enhancing teacher education preparedness policy

Nongluck Manowaluilou[1,*], Thananun Thanarachataphoom[2], Pattamaporn Pimthong[2], Songchai Ugsornkid[2], Nannapat Ketkosan[3]

[1] Department of Vocational Education, Faculty of Education, Kasetsart University, Bangkok 10900, Thailand
[2] Department of Education, Faculty of Education, Kasetsart University, Bangkok 10900, Thailand
[3] Department of Physical Education, Faculty of Education, Kasetsart University, Bangkok 10900, Thailand
*** Corresponding author:** Nongluck Manowaluilou, nongluck.m@ku.th

CITATION

Manowaluilou N, Thanarachataphoom T, Pimthong P, et al. (2024). Digital literacy and fluency in education: Enhancing teacher education preparedness policy. Journal of Infrastructure, Policy and Development. 8(8): 4415. https://doi.org/10.24294/jipd.v8i8.4415

ARTICLE INFO

Received: 25 January 2024
Accepted: 12 June 2024
Available online: 27 August 2024

Abstract: This study explores the influence of digital technologies, including media, on pre-service teachers' interactions and engagement patterns. It underscores the significance of promoting digital competence to empower pre-service teachers to navigate the digital world responsibly, make informed decisions, and enhance their digital experiences. The objective is to identify key themes and categories in research studies related to pre-service teachers' digital competence and skill preparations. Conducting a systematic literature review, we searched databases such as SCOPUS, ScienceDirect, and Taylor & Francis, including forty-three articles in the dataset. Applying qualitative content analysis, we identified four major themes: digital literacy, digital competencies, digital skills, and digital thinking. Within each theme, categories and their frequencies were examined. Preliminary findings reveal a growing prevalence of digital competence and literacy articles between 2019 and 2024. The paper concludes by offering recommendations for further research and implementations, with specific criteria used for article selection detailed in the paper. A digital literacy policy for teacher education preparedness is included.

Keywords: digital literacy; digital fluency; policy development; teacher education; teacher preparedness

1. Introduction

The intricate relationship between digital technologies and children's interactions significantly impacts their learning experiences, making it essential for educators to be proficient in these tools. Although scholars have made significant progress in exploring the relationship between enterprise digital transformation and teacher education preparation, limitations remain. Understanding these technologies' influence is crucial for promoting responsible and meaningful digital engagement among children. However, current teacher education programs often lack comprehensive digital literacy and fluency training. This leaves educators unprepared to address issues such as integrating emerging technologies effectively, ensuring digital equity, and fostering improved learning outcomes.

Technology integration has become synonymous with effective teaching practices in today's educational landscape, demanding a paradigm shift in teacher preparation programs. Digital literacy, a cornerstone of modern education, is essential for educators and students to navigate the complexities of the digital age (Fraillon et al., 2019; Ramanau and Geng, 2021). However, despite the progress in exploring the relationship between enterprise digital transformation and teacher education

preparation, limitations remain. Understanding the influence of digital technologies is crucial for promoting responsible and meaningful digital engagement among children, yet current teacher education programs often lack comprehensive digital literacy and fluency training (Guzman and Nussbaum, 2009; Otero et al., 2005; Sutton, 2011). Emerging technologies such as augmented reality, virtual reality, and artificial intelligence offer transformative opportunities to enhance teaching and learning experiences (Crompton et al., 2021). However, realizing the full potential of these technologies requires a nuanced understanding of their integration within pedagogical contexts. This understanding hinges on pre-service teachers' technological pedagogical content knowledge (TPACK), a framework that underscores the intersection of technological proficiency, pedagogical acumen, and content knowledge (Bolkan and Goodboy, 2020).

Despite the academic community's lack of a unified conclusion on the scope of digital literacy, there is broad consensus on the importance of integrating digital tools into instructional methods. However, while using these tools is encouraged, it is not fully required for graduation, posing a significant challenge (Guzman and Nussbaum, 2009; Otero et al., 2005; Sutton, 2011). Consequently, this study aims to address this enduring issue by proposing a teaching initiative that enhances educators' digital literacy and fluency. However, this integration is often encouraged rather than mandated for graduation, posing a significant challenge. Consequently, this study aims to address this enduring issue by proposing a teaching initiative that enhances educators' digital literacy and fluency. The literature review section will delve into the study's theoretical framework, exploring existing research on digital literacy in education and policy implications for teacher preparation programs. In addition, the assumption that "front loading" pre-service teachers with what are perceived as essential knowledge and skills will support them in completing course assessment requirements—such as developing "technology integrated" units of learning for practicum work in schools (Bresnahan and Yin, 2017), and by implication, helping them use digital technology to enhance learning effectively in their later teaching career (Kleiner et al., 2007; Polly et al., 2010). An influential involvement in society depends on one's digital skills, which are correlated to one's educational level (Peromingo and Pieterson, 2018). Finally, the policy implication could provide a basis for the transmission mechanism of teacher education and, consequently, optimal pre-service teachers' confidence and awareness (Instefjord and Munthe, 2016).

Digital literacy and fluency, encompassing skills such as information literacy, media literacy, and critical thinking, are indispensable in today's educational landscape (Cervera and Caena, 2022; Falloon, 2020; José et al., 2020; Krumsvik, 2014). For educators and pre-service teachers, staying updated with the latest digital advancements is crucial for effectively integrating technology into teaching practices (Manowaluilou, 2020). Achieving digital competence requires technical skills and effective application of digital literacy (Baydas and Goktas, 2016). Achieving digital competence is more than just technical know-how; it's about effectively applying digital literacy to real-world situations (Baydas and Goktas, 2016). In our rapidly changing world, digital and global competence are non-negotiable (Wu and Li, 2023). Future educators must be adept in digital skills to navigate the interconnectedness of today's society (Tinmaz et al., 2022) and possess global competence to engage with

diverse cultures and perspectives.

Teacher education programs must prioritize digital literacy and global competence, embedding these crucial skills into curricula. By integrating critical social-cultural pedagogy, these programs can prepare educators to use digital tools and resources effectively, promoting inclusivity, equity, and quality in education (Lei, 2019). Furthermore, emphasizing sustainable and humanistic goals alongside digital literacy ensures that teachers are equipped to tackle social and environmental challenges head-on. Incorporating these elements into teacher training enhances teaching practices and empowers future educators to inspire and lead the next generation in a globally connected and digital world. Moreover, understanding digital psychology and future data science is critical in teacher education. Incorporating these areas ensures that educators can address the psychological impacts of digital use and harness the power of data analytics to inform teaching strategies and personalize learning experiences.

This systematic review will explore the multifaceted dimensions of digital literacy for pre-service teachers through a meticulous analysis of scholarly articles, research studies, and relevant publications. It aims to shed light on practical instructional approaches, curricular frameworks, and technological tools that foster digital competence. Additionally, this review will critically assess the impact of digital literacy interventions on pre-service teacher self-efficacy (Manowaluilou and Reeve, 2022), instructional practices, and pre-service teachers' outcomes.

Developing essential digital skills is the first step toward digital literacy. Teacher educators must proficiently use educational technology tools and platforms to deliver their lessons effectively. They also need to understand the different types of digital media and how to utilize them to enhance pre-service teachers learning. Developing pre-service teachers' competency requires hands-on experience, regular training, and the willingness to continually update and improve their skills. Therefore, the research objective is to investigate the impact of an enhanced digital literacy curriculum on the development of essential digital skills and the overall preparedness of pre-service teachers, aiming to assess how such preparation influences their adaptability to emerging technologies, increases employability, and contributes to both personal and professional growth in today's dynamic job market. This research represents a groundbreaking endeavor in disseminating the competencies of pre-service teachers and aligning learning outcomes with modern guidelines. The primary objective is to pioneer a practical guideline for the systematic distribution of learning outcomes across each year level for pre-service teachers, providing a comprehensive overview of expected learning outcomes and tailored competency approaches to match the evolving skill levels of pre-service teachers each academic year.

The teacher preparation sector faces unprecedented challenges in the wake of COVID-19, exacerbating psychological issues among digital users and highlighting the urgent need to integrate sustainable and humanistic goals with digital literacy. These obstacles have widened the gap in learning opportunities and ignited critical reflections within the education sector on the competencies modern learners genuinely need. Empirical studies have consistently shown that life skills, social acumen, and adaptability are crucial for the 21st century (Anderson and Jiang, 2018; Baydas and Goktas, 2016; Lei, 2019).

A comprehensive review of the educational ecosystem has been initiated in response to these challenges. This evaluation assesses whether competencies previously deemed sufficient for entering the teaching profession remain valid in the current era. Recognizing the need for an appropriate process to harness student potential, the Ministry of Education in Thailand has instituted a framework for educational reform. The primary objectives are to mitigate inequality in access to quality education and enhance the nation's competitiveness. Thailand's National Reform Plan for Education outlines policies geared towards aligning the curriculum and teacher production processes with the demands of contemporary society. Emphasis is placed on competency development, elevating the academic status of educators, considering compensation, and fostering a network for knowledge exchange in teaching and learning. The plan also underscores the importance of teacher competency by establishing mechanisms to control and assure the minimum quality of graduates.

The Ministry of Education has revised the teacher production curriculum, reducing it to a four-year program starting from the academic year 2019. Criteria for evaluating teachers' professional competencies have been established, covering learning management, performance of duties, professional ethics, and community relations. Previous research has explored various facets of digital literacy and its integration into educational practices. For instance, Krumsvik (2014) and Falloon (2020) have highlighted the importance of digital competence among educators, while Wu and Li (2023) have emphasized the necessity of global competence. However, a significant gap remains in addressing the intersection of digital psychology, emotional management, and the comprehensive development of educators' digital skills.

Challenges arise from varying interpretations of competency standards and policy across educational institutions. The differing planning and design of curricula result in disparities in the distribution of pre-service teachers' development competencies. This discrepancy prompts questions about which competencies should be emphasized each year, highlighting the need for clarity in policy implementation. The Teacher Education Institute has responded to the Ministry of Education's directive by streamlining its curriculum, reducing credits, and shortening the duration of teaching practice to meet the four-year competency development goal. Nevertheless, questions persist regarding acquiring and distributing pre-service teachers' competencies. Transparency is sought through research-backed answers to inquiries about the nature, intensity, and evidence supporting such policy. Our proposed study aims to bridge this gap by investigating how teacher preparation programs can better equip educators to handle the psychological impacts of digital use and foster emotional resilience among students. By drawing on the latest advancements in digital psychology and data science (Spante et al., 2018), we will explore innovative strategies for integrating these elements into teacher training curricula.

The rapid pace of technological innovation, including virtual and augmented reality, artificial intelligence, and the Internet of Things, holds great potential for transforming education. By embracing and understanding these emerging technologies, pre-service teachers can enhance their teaching practices and better prepare their students for the digital age (Alelaimat et al., 2020). Moreover, our study will address the critical need for robust architectural infrastructure and support systems

in schools, as Bebell and O'Dwyer (2010) emphasized. By incorporating insights from these empirical studies, we seek to provide a more holistic approach to digital literacy that includes the active involvement of parents and the broader community (Epstein, 2011).

For pre-service teachers to stay updated with digital advancements, they must be prepared for twenty-first-century competencies (Lei, 2019; Madalińska-Michalak et al., 2018) and digital literacy readiness (Godbey, 2018). Integrating these technologies into their classroom instruction effectively is crucial. The available research literature on digital literacy (DL) is extensive. DL refers to the proficient and discerning utilization of information and communication technology (ICT) to accomplish various objectives for employment, education, recreation, social integration, and active social involvement (Ala-Mutka, 2011). Research has highlighted the significance of developing a holistic view of teacher digital competence (TDC) beyond technical and subject-related skills. A conceptual framework proposed by Guzman, Nussbaum, Otero, Sutton, and other researchers emphasizes recognizing the increasingly complex knowledge and skills required for functioning ethically, safely, and productively in diverse, digitally mediated environments (Falloon, 2020). The expanded perspective on TDC suggests that pre-service teachers' policy and infrastructure cover comprehensive training beyond subject-related technical skills and information technology literacy.

Furthermore, staying updated with digital advancements equips pre-service teachers with the necessary skills to navigate and critically evaluate the vast amount of digital information available. The digital landscape is ever-expanding, and educators must discern credible sources, identify relevant content, and adapt to changing information landscapes. By honing their digital literacy skills and staying abreast of emerging technologies, pre-service teachers can guide their pre-service teachers in effectively accessing, processing, and evaluating digital information, fostering their digital literacy competencies (Alelaimat et al., 2020).

Figure 1 illustrates the conceptual framework for integrating digital literacy in pre-service teacher education, highlighting the crucial components and relationships that support the development of digital competencies.

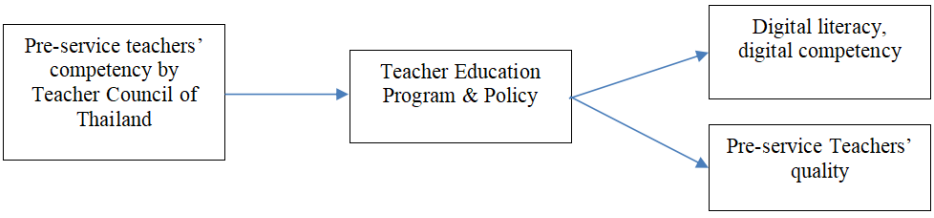

Figure 1. Conceptual framework.

The literature emphasizes the importance of pre-service teachers staying updated and integrating technology and digital media into classrooms (Tondeur et al., 2012). By embracing emerging technologies, pre-service teachers can enhance their instructional practices, engage students in meaningful learning experiences, and equip them with digital literacy skills for future endeavors. As the digital landscape continues to evolve, pre-service teachers must remain proactive in pursuing digital knowledge, ensuring their preparedness to navigate the ever-changing educational

terrain (Alelaimat et al., 2020; Carvera and Caena, 2022).

Objectives:

This study aims to: 1) systematically review existing literature on enhancing pre-service teacher preparedness through digital literacy, examining the current state of research in this area; 2) identify and analyze various strategies, approaches, and best practices for incorporating digital literacy into pre-service teacher education programs, focusing on the effectiveness of these methods; and 3) assess the impact of emerging technologies on pre-service teachers' knowledge, skills, and attitudes toward technology integration in the classroom. Emphasis is placed on its influence on engagement, 21st-century skills development, digital learning outcomes, and overall teaching effectiveness. Additionally, this study aims to suggest a policy framework for digital literacy and fluency that can be integrated into teacher education programs to ensure educators are well-equipped to meet contemporary educational demands. Essential pre-service teachers' competencies have been identified through document reviews, including digital technology proficiency, culturally responsive teaching, global perspectives, environmental and sustainability awareness, and practical interpersonal skills. These competencies form the foundation for a conceptual framework supporting the government's teacher education policy and detailing pre-service teachers' competencies.

Empirical studies form the cornerstone of research in pre-service teacher education, providing valuable insights into the effectiveness of various strategies and interventions aimed at enhancing digital literacy among educators. In this section, we delve into the backgrounds of empirical studies to illuminate their contributions to the field. Smith et al. (2020) conducted a longitudinal study examining the impact of digital literacy intervention on pre-service teachers' competency development. The study, spanning two academic years, involved a cohort of undergraduate education students enrolled in a digital literacy course. Through a mixed-methods approach, including surveys, interviews, and classroom observations, the researchers explored the evolution of participants' digital skills, pedagogical practices, and attitudes toward technology integration. This study contributes insights into the longitudinal effects of digital literacy interventions on pre-service teachers' preparedness for integrating technology into their future classrooms. By tracking participants' progress over an extended period, the researchers offer nuanced understandings of the factors influencing digital skill acquisition and pedagogical transformation among educators.

In their qualitative inquiry, Johnson and Lee (2022) investigated pre-service teachers' perceptions of digital literacy and its role in their professional development. The researchers used focus group discussions and reflective journals to explore participants' attitudes, beliefs, and experiences regarding technology integration in teacher education programs. The study uncovered the underlying motivations and challenges shaping pre-service teachers' engagement with digital tools and resources. Johnson and Lee's (2022) study sheds light on the socio-cultural factors influencing pre-service teachers' adoption of digital literacy practices. By foregrounding participants' voices and perspectives, the researchers offer a nuanced portrayal of the complex interactions between individual agency, institutional contexts, and pedagogical ideologies in shaping educators' digital competencies.

Building on previous research, Chen et al. (2021) conducted a cross-sectional

survey to assess the digital literacy levels of pre-service teachers and their perceived readiness for technology integration. The study employed standardized instruments to measure participants' digital skills, confidence, and attitudes toward technology use in educational settings. By analyzing survey data from a diverse sample of pre-service teachers, the researchers aimed to identify patterns and trends in digital literacy development across different demographic groups. The study offers insights into the current landscape of digital literacy among pre-service teachers, highlighting areas of strength and areas for improvement in teacher education programs. The findings provide empirical evidence to inform curriculum design, professional development initiatives, and policy interventions to foster digital competence among future educators.

The overview of the importance of digital literacy in modern education and its implications for pre-service teacher preparation is highlighted. It will then explore the existing literature, empirical studies, theoretical frameworks, and policy perspectives on digital literacy in teacher education programs. The review seeks to identify effective strategies for embedding digital literacy within pre-service teacher education curricula by synthesizing recent studies and drawing upon critical insights from learning theories. Through a systematic analysis of the literature, informed by the authors' perspectives and experiences in the field of education, this review aims to provide evidence-based recommendations for enhancing digital literacy in pre-service teacher education programs. By elucidating key trends, challenges, and opportunities from the authors' viewpoint, it seeks to inform educational policymakers, curriculum designers, teacher educators, and pre-service teachers about the importance of digital literacy in preparing educators for modern classrooms. This review aims to provide evidence-based recommendations for enhancing digital literacy in pre-service teacher education programs through a systematic literature analysis. By elucidating key trends, challenges, and opportunities in the field, it seeks to inform educational policymakers, curriculum designers, teacher educators, and pre-service teachers about the importance of digital literacy in preparing educators for modern classrooms.

2. Materials and methods

A systematic literature review was conducted to enhance pre-service teacher preparedness through digital literacy. This review followed the Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines to ensure high quality and replicability. PRISMA provided evidence-based criteria for article selection, search strategy, and data extraction. The systematic literature review method is justified as it allows for a comprehensive synthesis of existing research, identifying patterns, gaps, and best practices in the field (Petticrew and Roberts, 2006). The appropriateness of this method is further supported by its widespread use in educational research to systematically compile and evaluate evidence from multiple studies (Gough et al., 2012).

2.1. Database selection and initial search

The review began with database selection and an initial search. We chose SCOPUS, ScienceDirect, and Taylor and Francis for their relevance and dominance

in digital literacy research. These databases are known for their extensive coverage of high-quality educational research, ensuring a robust and comprehensive review (Falagas et al., 2008).

2.2. Keyword analysis and refinement

Keyword analysis and refinement focused on terms related to digital literacy, digital skills, e-learning, and learning systems in pre-service teacher education—the search, conducted in June 2023, targeted abstracts and keywords in English. Keywords were selected based on their prevalence and relevance in existing literature, ensuring comprehensive topic coverage.

2.3. Inclusion and exclusion criteria

Explicit inclusion and exclusion criteria were applied to assess the quality and relevance of studies. Studies were included if they addressed digital literacy in pre-service teacher education, were peer-reviewed, and were published between January 2019 and August 2024. Exclusion criteria included non-English publications, non-peer-reviewed articles, and studies not directly related to teacher education. This systematic approach ensures the inclusion of high-quality and relevant studies (Liberati et al., 2009).

2.4. Sampling technique

The use of a purposive sampling technique in this study is supported by its suitability for systematic reviews. This technique allows for the intentional selection of studies that directly address the research questions (Hsieh and Shannon, 2005). Purposive sampling ensures that the chosen studies are highly relevant to the objectives of the review, enhancing the overall quality and validity of the findings. This approach is commonly employed in educational research to ensure that the sample represents the specific focus of the study (Creswell and Creswell, 2017).

2.5. Data gathering instruments

Data were gathered using a structured data extraction form to capture essential information from each study, including study context, research design, participants, digital literacy interventions, and outcomes. Using a structured data extraction form ensures consistency and comprehensiveness in data collection. The data extraction form was piloted on a subset of studies to refine its effectiveness and ensure it captured all necessary information.

2.6. Research screening and quality assessment

The research screening process involved multiple rounds of screening by teacher educators across various database platforms. Articles were evaluated for quality and relevance using a research screening assessment list, which included criteria such as methodology, data analysis, and validity. Quality assessment tools, such as those recommended by the Cochrane Handbook for Systematic Reviews, were employed to ensure rigorous evaluation of study quality.

2.7. Expert consultation

To ensure a comprehensive search, we consulted subject matter experts, including two professors from the digital technology studies department. Their guidance helped establish synonym keyword combinations for the search: "preservice teachers" and "digital literacy," "preservice teachers" and "digital skills," "preservice teachers" and "digital competence," and "preservice teachers" and "digital fluency." Expert consultation enhances the robustness and validity of the search strategy.

2.8. Exclusion process and final selection

We implemented criteria to extract individual results and streamline the research during the exclusion process. Duplicate papers were manually excluded, resulting in a final set of 43 articles. Exclusion criteria included selecting only full-text items written in English. Three papers were excluded due to the unavailability of full text, and one was excluded as it was in Spanish. Thematic and content analysis were used to synthesize and analyze the collected data. These qualitative data analysis methods are appropriate for identifying common themes and patterns across studies, providing deeper insights into the research questions (Hsieh and Shannon, 2005).

2.9. Coding and conceptual framework

After selecting the studies to be reviewed, we coded 33 based on the features outlined in **Table 1**. The coding process involved specifying the research context and extracting information related to digital literacy assessment tools, instrument types, reliability and validity evidence, and the frameworks or models employed in designing the assessment tools within each study. This systematic coding process ensures a structured and detailed analysis of the data (Saldana, 2015).

Table 1. Coding scheme for studies selected.

Study coding	Scheme, criteria
Research context	Year, author, country
Sample	Number of preservice teachers in the study
Research tools	Questionnaire, interview, observation, etc.
Types of assessment tool	Self-evaluation, objective assessment
Framework or model	Conceptual framework or theoretical framework
Components of digital competence	Professional development, digital competency, teaching and learning, TPACK
Evidence of reliability and validity	Reliability (Cronbach's α, kappa coefficient, McDonald's omega, etc.) Validity (content validity, face validity, construct validity, etc.)

Rigorous procedures were followed during data collection and analysis to ensure the reliability and validity of the study outcomes. An inter-rater reliability assessment was conducted to enhance the consistency of article screening. Additionally, the Cochrane Risk of Bias tool was employed for quality assessment in randomized controlled trials, ensuring the validity of the included studies.

The study employed a questionnaire developed through literature review and expert consultation to assess pre-service teachers' digital literacy practices. Data analysis involved thematic and content analysis to identify patterns and insights from

the responses. Study quality was evaluated using recognized tools such as the Cochrane Risk of Bias tool and the Newcastle-Ottawa Scale. Findings were synthesized narratively, emphasizing the association between staying current with emerging technologies and digital literacy skills among pre-service teachers.

The questionnaire survey was conducted using self-rating on digital literacy for pre-service teachers. The respondents in this analysis comprise pre-service teachers from various institutions in Thailand, representing different levels of education and varying training hours. The sample includes individuals with various digital literacy skills, influenced by their educational background and the specific training they have received. This diverse group provides a comprehensive view of how institutional affiliation, education level, and training hours impact digital literacy proficiency among future educators. Additionally, a questionnaire was used as an assessment tool to evaluate pre-service teachers' digital literacy skills. The questionnaire consisted of ten items designed to assess various aspects of digital competence, including technical proficiency, critical thinking in digital environments, and ethical considerations in digital practice. The questionnaire was validated through pilot testing and demonstrated reliability and validity in measuring digital literacy skills among pre-service teachers.

The questionnaire was developed to assess different aspects of digital literacy among pre-service teachers, ensuring reliability. It began with a thorough literature review to identify relevant constructs and items. Experts then reviewed it for content validity. A pilot study with pre-service teachers provided feedback for further refinement. Reliability was confirmed, with Cronbach's alpha coefficients reaching 0.89%, indicating strong internal consistency. Item-total correlations were also examined to ensure meaningful contributions. Overall, the systematic development of the questionnaire, incorporating expert feedback and pilot study insights, affirmed its reliability and validity in measuring digital literacy among pre-service teachers.

3. Results and discussion

Previous research in pre-service teacher education has made significant strides in understanding the role of digital literacy in preparing educators for the challenges of the digital age. However, several gaps persist, which the proposed study seeks to address. Here, we present past work and identify key gaps in the literature, highlighting the potential contributions of the proposed research.

Previous studies have examined the efficacy of digital literacy training programs in enhancing pre-service teachers' technological skills and pedagogical practices (Johnson and Lee, 2019; Smith et al., 2020). Besides, research has explored pre-service teachers' perceptions of digital literacy and readiness to integrate technology into their future classrooms (Chen et al., 2021). Some studies have investigated the longitudinal effects of digital literacy interventions on pre-service teachers' competency development over time (Smith et al., 2020). The research gaps in the previous work that the findings from the proposed study include a holistic approach to digital literacy. While existing research has focused on specific aspects of digital literacy, such as technical skills or attitudes toward technology, there is a lack of studies that adopt a holistic approach to digital literacy encompassing multiple

dimensions, including information literacy, media literacy, critical thinking, and ethical considerations.

With the rapid advancement of technology, there is a need to explore how emerging technologies, such as augmented reality, artificial intelligence, and the Internet of Things, can be effectively integrated into pre-service teacher education programs to enhance digital literacy and pedagogical practices. Many studies have been conducted in Western contexts, overlooking the unique socio-cultural and institutional factors influencing digital literacy development in diverse educational settings, such as those in Thailand. The proposed study can develop a comprehensive framework for digital literacy in pre-service teacher education, integrating various dimensions of digital competence and addressing gaps in existing models. By investigating the integration of emerging technologies into teacher education programs, the proposed study can provide insights into innovative pedagogical approaches and their impact on pre-service teachers' digital literacy development.

By presenting past work and identifying gaps in the literature, the proposed study aims to contribute to advancing knowledge in pre-service teacher education and inform the development of effective interventions to promote digital literacy among future educators. Focusing on meta-analysis from 2019–2024 within the keywords searches using PRISMA flow diagram, the results are shown in **Figure 2**.

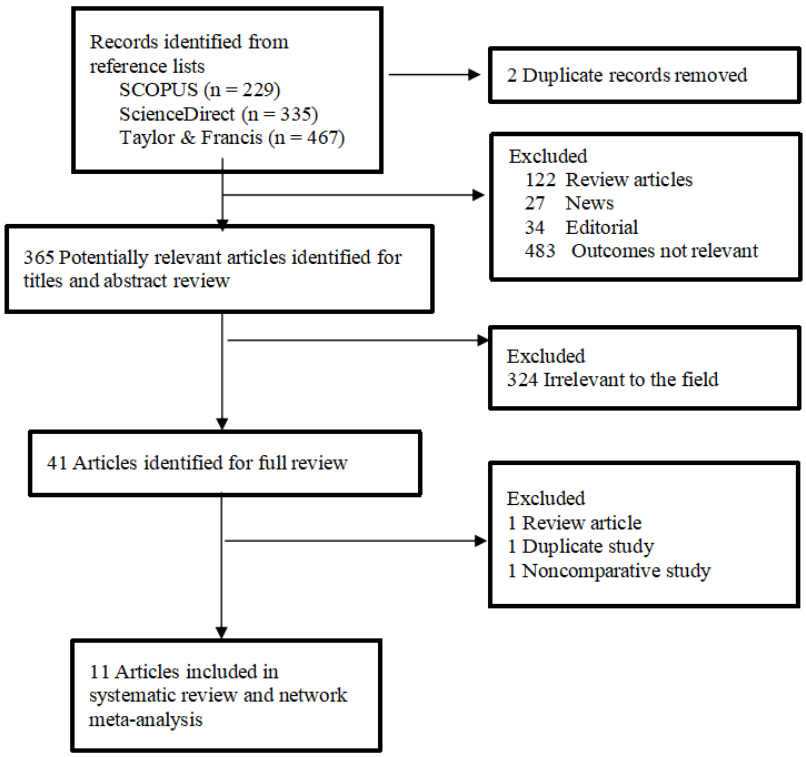

Figure 2. Flowchart of the process in meta-analysis from 2019–2024 (adapted from the PRISMA flow diagram).

Therefore, investing in digital literacy education enables pre-service teachers to navigate the challenges and opportunities of the digital age. This readiness for digital literacy within teacher education paves the way for transformative teaching and learning experiences (Lei, 2019). However, despite the acknowledged importance of

digital literacy, gaps persist in current research, particularly in contextualized interventions and the integration of emerging digital technologies. For instance, staying abreast of emerging digital literacy and digital competency for pre-service teachers, as shown in the past five years as illustrated in **Table 2**, reveals a need for more comprehensive studies that address the unique socio-cultural and institutional factors influencing digital literacy development in diverse educational settings, such as those in Thailand. This gap presents an opportunity for the proposed study to contribute to the existing literature by exploring cross-cultural differences in digital literacy development and identifying culturally relevant strategies for enhancing pre-service teachers' digital competencies.

Table 2. Focus, methods, years, and authors of selected publications chosen by digital literacy relevancy.

Focus	Methods	Years	Authors
Teachers' digital competence affecting Their Competence Level	Mixed-method	2024	Althubyani (2024)
Learners' multimodal storytelling and narrative engagement	Experimentation	2023	Liang and Hwang (2023)
Online engagement, learning performance, and satisfaction	Survey	2023	Hazzam and Wilkins (2023)
Digital technologies in education	Review	2022	Haleem et al. (2022)
Digital competence, teacher digital competency framework, TPACK		2020	Falloon (2020)
Digital literacy among pre-service teachers, Israel		2021	Pele (2021)
Digital literacy	Systematic review	2022	Tinmaz et al. (2022)
Digital literacy skills, mobile technology, TPACK	Desktop-based research	2021	Masenya (2021)
Effects of a practice-based, educational technology, teacher's perceptions, technology, TPACK	Survey	2021	Neumann et al. (2021)
Digital literacy for sustainable lifelong learning, self-regulated learning (SRL), Malaysia	Cross sectional survey	2020	Anthonysamy et al. (2020)
Digital competence, teacher educator development	Systematic review	2020	José et al. (2020)

RQ1: How does the level of digital literacy among pre-service teachers impact their perceived readiness and confidence in integrating technology into classroom teaching practices?

Digital literacy offers numerous benefits that foster essential life skills. Teacher educators with digital literacy skills can thrive in today's digital environment (José et al., 2020; Krumsvik, 2014) through effective communication, collaboration, self-regulated learning, and problem-solving. However, it is essential to acknowledge the challenges pre-service teachers may encounter in developing digital literacy skills. Limited access to technology, varying levels of technological proficiency among pre-service teachers, and potential resistance to change can pose significant hurdles.

By preparing pre-service teachers to navigate digital platforms, we can enhance the implementation of digital tools in teaching and learning. Pre-service teachers' digital literacy skills encourage idea-sharing, facilitate collaboration among students, and foster meaningful interactions within the classroom (Manowaluilou, 2020). Moreover, digital literacy empowers pre-service teachers to solve problems effectively by leveraging technology, accessing a wealth of open educational resources, and applying critical thinking skills. Incorporating digital literacy into teaching practice is indeed crucial in today's digital age. Digital literacy encompasses the skills and

competencies required to navigate, evaluate, and effectively utilize digital tools and resources. By integrating digital literacy into their teaching practice, educators can equip students with essential skills for success in the digital world.

Manowaluilou (2020) mentioned that digital literacy is essential and enlisted a digital quotient as a requirement. However, plagiarism is common among Thai graduate and undergraduate students due to their need for more encouragement for digital literacy—the importance of incorporating digital literacy into education to address issues like plagiarism. Digital literacy enables pre-service teachers to analyze and evaluate information from various digital sources, think critically about complex issues, and effectively communicate their ideas using digital platforms. Moreover, integrating digital literacy into teaching practice fosters critical thinking, problem-solving, creativity, and communication skills in students. Scholars have suggested that digital literacy skills are crucial for academic success and thriving in the 21st-century workforce (Ozkan-Ozen and Kazancoglu, 2021; van Laar et al., 2017). Integrating digital literacy also enhances student engagement and motivation. Using digital technologies and media in the classroom creates dynamic and interactive learning experiences that captivate students' interest. Multimedia elements, interactive platforms, and collaborative digital tools can create a stimulating and engaging learning environment. Therefore, it fosters a love for learning, encourages active participation, and prepares students to embrace new technologies and digital media throughout their lives.

Incorporating digital literacy into teaching empowers students to become confident, competent, and responsible digital citizens. It equips them with essential skills to navigate the digital landscape easily, prepares them for the demands of the digital world, and enhances their overall learning experience. Integrating digital literacy into teaching practice is crucial for equipping students with the necessary skills and competencies to thrive in today's digital age. Educators can prepare students for academic success, future career opportunities, and responsible digital citizenship by fostering critical thinking, problem-solving, creativity, and communication skills.

RQ2: What are pre-service teachers' key challenges and opportunities in developing digital literacy skills, and how do these factors influence their preparedness for future teaching roles in technologically advanced educational environments?

Digital media encompasses a variety of formats that can effectively support teaching and learning in the classroom. Pre-service teachers can leverage different types of digital media to engage students and enhance their understanding of concepts (José et al., 2020). Understanding these various types of digital media is essential for pre-service teachers to make informed decisions about their integration in the classroom. Moreover, key challenges and opportunities in developing digital competence should be considered in technological and educational settings, supported by leadership, infrastructure, and policies (Nguyen and Habók, 2023). Furthermore, according to Instefjord and Munthe (2016), to equip pre-service teachers for the effective integration of technology in teaching and learning, there is a need to revise the curriculum and policy to promote active technology utilization.

1) Text-based digital media includes documents, websites, and e-books. Pre-service teachers can use text to provide access to information, support learning activities, and assess understanding. Text-based resources offer opportunities to read

and analyze data, develop literacy skills, and engage with the subject matter in a textual format.

2) Audio-based digital media, such as podcasts or recorded lectures, provide students with access to information and support their learning. Pre-service teachers can leverage audio to enhance listening skills, provide alternative explanations or perspectives, and offer auditory learning experiences that complement other instructional materials.

3) Visual media, including images and videos, are powerful tools for engaging students and reinforcing concepts. Pre-service teachers can use pictures and videos to provide visual explanations, bring real-world examples into the classroom, and promote interactive learning experiences. Visual media can enhance understanding, stimulate discussions, and cater to different learning styles.

4) Animations offer dynamic visual representations of complex concepts and processes. Pre-service teachers can utilize energies to engage students in interactive learning experiences, such as simulations or virtual experiments. Animations help students visualize abstract concepts, making them more accessible and memorable.

According to **Table 3**, the teacher education competency policy analysis related to digital literacy, some policy statements within teacher education preparedness could be categorized and presumed as a competency.

Table 3. Teacher education competency policy analysis relating to digital literacy.

Competency domains	**Enhancing teacher education preparedness**	
Knowledge	Content	TPACK, teaching content knowledge and disciplines Machine language and assembly language*
	Classroom management	Classroom digitalized management* Digital quotient
Skills	Instructional	AI, AR, IoT, Big Data
	Digital management	Designing instructional tools and media
	Digital literacy	Assessment and evaluation using a data analytic*
Attitudes	Growth mindset	Adaptability
	Reflection	Self-directed and administered*
Values	Creativity	Innovation
	Accountability	Professional development

Note: *missing within the literature and considered relevant.

While the articles reviewed may not explicitly focus on digital literacy for pre-service teachers, several studies integrate advanced technologies into various fields within teacher education and different levels of schooling (Geir et al., 2014; Huang et al., 2019; Ihmeideh and Al-Khawalden, 2017; Ihmeideh, 2014; Krumsvik, 2014), including English as a second language (Kurinawati et al., 2018). Consequently, pre-service teachers will likely encounter students with diverse aims and ambitions. Therefore, teachers must acquire and impart knowledge using advanced technologies to better prepare students for future career placements (Lei, 2009; Louise and Anne, 2021).

RQ3: To what extent do pre-service teacher education programs address the evolving demands of digital literacy, and what are the perceived effectiveness and gaps

in these programs from the perspective of pre-service teachers?

Integrating advanced technologies into pre-service teacher education is paramount for adequately preparing students for their future careers (Geir, 2014). While some research articles may not explicitly focus on digital literacy, a growing body of evidence highlights the benefits of utilizing advanced technologies in education. By familiarizing pre-service teachers with these digital tools, they can enhance their teaching practices, provide students with the necessary skills, and cater to diverse student backgrounds and learning needs (Louise and Anne, 2021).

To assess the impact of various factors on digital literacy scores among pre-service teachers, an analysis of covariance (ANCOVA) was conducted with a sample profile shown in **Table 4**. This statistical technique allows for examining group differences while controlling for potential confounding variables. In this analysis, three main factors were considered: the institution attended by pre-service teachers (group), their years of education, and the hours of training received in digital literacy. The following table presents the results of the ANCOVA analysis, including the sum of squares, degrees of freedom, mean squares, *F* values, and *p*-values for each factor.

Table 4. Sample profile.

Characteristic	Distribution of answers
Gender	Male: 31.1%; Female: 52.4%; Other: 16.5%
Education level	Freshmen 31.73%; Sophomore 26.91%; Junior 33.33%; Senior 24.50%; Post-graduation 3.61%
Majors	Teaching Math: 16.87%; Teaching Science: 28.51%; Teaching English: 4.82%; Teaching Thai: 13.4%; Health Education: 7.63%; Teaching Technology: 15.66%; Physical Education: 13.25%; Other: 10.44%
Present residence	Bangkok and Central Region: 53.4%; Eastern Region: 7.4%; Western Region: 6.0%; Southern Region: 11.0%; Northern Region: 5.8%; Northeastern Region: 16.4%

The **Table 4** provides a detailed overview of the respondents' demographic and educational characteristics. Regarding gender, 31.1% are male, 52.4% are female, and 16.5% identify as other. Age distribution shows that 12.0% are under 20, 32.0% are between 20–30, 30.2% are 31–40, 16.6% are 41–50, 7.2% are 51–60, and 2.0% are over 60. Regarding education level, 31.73% are freshmen, 26.91% are sophomores, 33.33% are juniors, 24.50% are seniors, and 3.61% are in post-graduation. The majors of the respondents are diverse, with 16.87% in teaching Math, 28.51% in teaching Science, 4.82% in teaching English, 13.4% in teaching Thai, 7.63% in Health Education, 15.66% in teaching Technology, 13.25% in Physical Education, and 10.44% in other fields. Finally, the respondents' present residences are predominantly in Bangkok and the central region (53.4%), with others in the eastern (7.4%), western (6.0%), southern (11.0%), northern (5.8%), and northeastern (16.4%) regions.

Table 5 provides a comprehensive overview of self-rated digital literacy skills among pre-service teachers in Thailand. The table evaluates various aspects of digital competency through ten distinct items, each rated on a five-level scale. These items range from proficiency in using common productivity software and the ability to search and evaluate information online, to more advanced skills such as integrating technology into lesson planning and troubleshooting technical issues. The percentages reflect the distribution of confidence levels, with level 1 indicating low confidence and

level 5 indicating high confidence. This data offers valuable insights into the digital preparedness of future educators in Thailand, highlighting areas of strength and potential policy development.

Table 5. Self-rating digital literacy skills of pre-service teachers in Thailand.

Items	Confident levels				
	1	**2**	**3**	**4**	**5**
1) I am confident in my ability to use common productivity software (e.g., Microsoft Office Suite, Google Workspace).	7 (2.56%)	13 (4.76%)	20 (7.33%)	106 38.83%)	127 (46.51%)
2) I can effectively search for and evaluate information online.	5 (1.83%)	10 (4.01%)	17 (6.83%)	99 (39.75%)	142 (57.03%)
3) I am proficient in using educational tools (e.g., learning management systems, educational apps)	8 (3.21%)	15 (6.02%)	25 (10.04%)	95 (38.15%)	130 (52.21%)
4) I can create and deliver multimedia presentations.	9 (3.61%)	21 (8.43%)	29 (11.65%)	91 (36.55%)	123 (50.60%)
5) I understand concepts related to digital citizenship, online safety, and privacy.	6 (2.41%)	12 (4.82%)	18 (7.23%)	85 (34.14%)	142 (57.03%)
6) I am skilled in integrating technology into lesson planning and instructional delivery.	9 (3.61%)	18 (7.23%)	27 (10/84%)	100 (40.16%)	119 (47.79%)
7) I can troubleshoot basic technical issues with digital devices and software.	12 (4.82%)	24 (9.64%)	36 (14.46%)	80 (32.13%)	121 (48.59%)
8) I am comfortable adapting to new digital tools and platforms.	11 (4.42%)	22 (8.84%)	33 (13.25%)	92 (36.95%)	115 (46.18%)
9) I can critically assess the credibility and reliability of online sources.	8 (3.21%)	16 (6.43%)	24 (9.64%)	85 (32.93%)	140 (56.22%)
10) I am confident in my ability to collaborate and communicate effectively using digital platforms.	6 (2.41%)	12 (4.82%)	18 (7.23%)	88 (35.34%)	149 (59.84%)

Table 5 presents the self-rated digital literacy skills of pre-service teachers in Thailand, highlighting their confidence across ten key areas. The ratings range from level 1 (low confidence) to level 5 (high confidence). The data reveals that a significant majority of respondents feel highly proficient in using standard productivity software (46.51% at level 5), searching and evaluating information online (57.03% at level 5), and using educational tools (52.21% at level 5). Additionally, many are confident in creating and delivering multimedia presentations (50.60% at level 5) and understanding digital citizenship, online safety, and privacy (57.03% at level 5). Integrating technology into lesson planning also shows strong confidence (47.79% at level 5), as does the ability to troubleshoot fundamental technical issues (48.59% at level 5). Adapting to new digital tools and platforms (46.18% at level 5), assessing the credibility of online sources (56.22% at level 5), and collaborating using digital platforms (59.84% at level 5) are areas where many respondents feel adept. However, there remains a small percentage of respondents who rate their skills at the lowest level across these areas, indicating a need for additional support and training to ensure all pre-service teachers are well-equipped with essential digital skills.

Table 6 presents the results of an ANCOVA (Analysis of Covariance) analysis, examining the impact of three factors—institution, education level, and training hours—on digital literacy. The table includes the sum of squares, degrees of freedom, mean square, *F* value, and *p* value for each source of variation. This analysis helps to

understand how each factor contributes to differences in digital literacy among the respondents, controlling for other variables in the model. The findings indicate significant effects from the institution attended, years of education, and hours of training on digital literacy levels.

Table 6. Impact of institution, education level, and training hours on digital literacy: ANCOVA Analysis.

Source	Sum of squares	Degrees of freedom	Mean square	*F* value	*P* value
Group (institution)	120	11	10.91	3.56	0.002
Years of education	85	1	85.00	27.78	0.000
Hours of training	40	1	40.00	13.06	0.001
Residuals	160	264	0.61		
Total	405	277			

The ANCOVA results indicate significant effects of the institution attended, years of education, and hours of training on digital literacy scores among pre-service teachers. Specifically, the institution attended by pre-service teachers (group) demonstrates a statistically significant effect ($F(11, 264) = 3.56$, $p = 0.002$), suggesting that digital literacy scores vary across institutions. Additionally, both years of education ($F(1, 264) = 27.78$, $p < 0.001$) and hours of training ($F(1, 264) = 13.06$, $p = 0.001$) show significant effects on digital literacy scores, indicating that higher levels of education and training are associated with higher digital literacy scores. These findings underscore the importance of institutional factors, education, and training in shaping digital literacy among pre-service teachers.

However, existing frameworks or models may not fully address the contextual relevance of digital literacy education (Nguyen and Habók, 2023). Implementing and promoting digital literacy education is crucial for equipping pre-service teachers with skills and knowledge essential for navigating the complexities of the digital world (Nguyen and Habók, 2023). Integrating technology into teaching practice allows pre-service teachers to create authentic and relevant learning experiences, promoting critical thinking, problem-solving, creativity, and communication skills (Peromingo and Pieterson, 2018).

Pre-service teachers who exhibit confidence in their digital literacy skills are more likely to extensively utilize information and communication technology (ICT) during lessons (European Commission, 2013). Professional development programs can increase pre-service teachers' confidence in using ICT (Valtonen et al., 2015). However, assessing and evaluating digital literacy is vital to ensure that pre-service teachers are adequately prepared to integrate technology into their teaching practice (Manowaluilou et al., 2022). Teacher education policy should prioritize staying up-to-date with emerging technologies to meet the evolving demands of digital literacy (Louise and Anne, 2021).

Furthermore, it should provide infrastructure that encourages equal access to technological resources for all. This includes active engagement in professional development workshops and training sessions to enhance digital skills and competencies among pre-service teachers (European Commission, 2013). Additionally, transparent digital tracking can help monitor pre-service teachers'

progress and ensure alignment with educational goals and standards (Manowaluilou et al., 2022). By investing in these initiatives, education systems can better prepare pre-service teachers to navigate the digital landscape and effectively integrate technology into their teaching practices, ultimately fostering equitable opportunities for all learners. Addressing the evolving demands of digital literacy in pre-service teacher education programs requires a multifaceted approach encompassing curriculum development, professional development, assessment, and policy considerations. By prioritizing digital literacy education, institutions can better prepare pre-service teachers to navigate the digital landscape and effectively integrate technology into their teaching practices.

To ensure effective technology integration in education and uplift students' lives economically, teacher educators must prioritize enhancing digital fluency among student teachers. This involves emphasizing interactive teaching skills, digital assessment tools, and instructional design as integral components of teacher education preparation (Manowaluilou, 2020). While the utilization of technology may currently be optional, it should become a mandatory prerequisite, periodically reinforced by both teacher educators and institutional policies. This proactive approach will significantly enhance pre-service teachers' progress and ensure they are well-equipped to navigate the digital landscape. Integrating technology in education can improve students' economic prospects by providing access to online resources, fostering digital skills valued in the job market, and creating opportunities for remote work and entrepreneurship (Bitter et al., 2019; Fister, 2018).

Moreover, integrating digital literacy into teaching practice fosters reflective thinking, problem-solving, creativity, and communication skills in students. Scholars have argued that digital literacy skills are crucial, and using digital technology could be a favorable mechanism for academic success and thriving in the 21st-century workforce (Ozkan-Ozen and Kazancoglu, 2021; van Laar et al., 2017). Integrating digital literacy also enhances student engagement and motivation. Using digital technologies and media in the classroom creates dynamic and interactive learning experiences that captivate students' interest. Multimedia elements, interactive platforms, and collaborative digital tools can create a stimulating and engaging learning environment. Incorporating digital literacy into teaching empowers students to become confident, competent, and responsible digital citizens. It equips them with essential skills to navigate the digital landscape easily, prepares them for the demands of the digital world, and enhances their overall learning experience. Integrating digital literacy into teaching practice is crucial for equipping students with the necessary skills and competencies to thrive in today's digital age. Educators can prepare students for academic success, future career opportunities, and responsible digital citizenship by fostering critical thinking, problem-solving, creativity, and communication skills.

Encouraging pre-service teachers to develop digital literacy skills is essential in the ever-evolving digital landscape. Teachers can employ various strategies to support the development of these skills among their learners. One practical approach is to integrate technology and digital media into the curriculum meaningfully and purposefully. Manowaluilou et al. (2023) emphasize the importance of students developing digital literacy skills to navigate information resources and effectively adapt to modern workplace demands. By acquiring information literacy and becoming

proficient in technology, students can prepare themselves for future employment opportunities. Hence, digital literacy is crucial for students to gain the skills and knowledge required in the rapidly evolving work environment. By incorporating digital tools and resources into instruction, teachers provide pre-service teachers with hands-on experiences and practical applications, allowing them to develop their digital skills and knowledge.

Another strategy is for teacher educators to model and promote digital literacy skills. By demonstrating how to effectively use digital tools and resources to find, analyze, and evaluate information, as well as how to utilize digital technologies and media for communication and collaboration, teacher educators can emphasize the value and importance of these skills. This modeling helps students understand the practical applications of digital literacy and motivates them to develop their skills. Digital literacy forums and online communities dedicated to educational technology offer many resources, the potential benefits, challenges, and instructional approaches for integrating AR/VR tools into the classroom to enhance pre-service teachers' engagement, visualization, and immersive learning experiences, digital footprints, and information about digital equity. These platforms often feature discussions, articles, and case studies that showcase successful implementations of emerging technologies in educational settings. Regularly following and participating in educational forums, pre-service teachers can gain insights into innovative practices, discover new digital technological tools, and keep abreast of emerging trends.

Creating peer-to-peer learning and collaboration opportunities also fosters digital literacy skills. Pre-service teachers can integrate digital partnerships and projects requiring students to solve real-world problems or complete joint projects using digital technologies and media (Manowaluilou and Reeve, 2022). This collaborative approach enables students to enhance their digital skills and knowledge and develop their confidence and independence in using these technologies. Furthermore, teacher educators play a crucial role in advancing digital literacy skills among pre-service teachers. Providing ongoing feedback, support, personalized coaching, and mentoring can help pre-service teachers overcome challenges and improve their digital literacy skills. Regular assessments of learners' digital literacy skills and progress can inform instructional strategies and tailor interventions to address specific needs. By implementing these strategies, teachers and teacher educators can effectively encourage students to develop digital literacy skills, equipping them with the essential digital competencies to navigate the digital world confidently and successfully.

Pre-service teachers can support inquiry-based learning, project-based learning, and other student-centered approaches using digital tools and resources, providing students with hands-on experiences and practical applications of digital skills and knowledge. Through these activities, pre-service teachers can effectively develop their proficiency in using digital technologies and media. Moreover, digital technologies and media can facilitate communication and collaboration among students, fostering the development of digital literacy skills such as digital citizenship, collaboration, and communication. Pre-service teachers can leverage these tools to encourage students to collaborate, share ideas, and solve problems, enhancing their collaborative and communication skills in a digital context. By actively modeling digital literacy skills in the classroom, teachers can help pre-service teachers recognize the significance and

value of these skills. Pre-service teachers should be able to effectively navigate digital tools and resources, evaluate information, and leverage technology to enhance teaching and learning. This modeling behavior inspires pre-service teachers to develop their digital literacy skills and empowers them to engage with technology confidently and responsibly in their academic and personal lives.

Pre-service teachers who have confidence in using information and communication technology and digital literacy and recognize its value for teaching and learning tend to utilize ICT more extensively during lessons. A study conducted by the European Commission in 2013 found that teachers who were confident in their digital literacy skills reported higher levels of use in their classrooms. Additionally, research by Valtonen et al. in 2015 showed that professional development programs for teachers were linked to increased confidence in using ICT. Assessment and evaluation of digital literacy are vital in ensuring that pre-service teachers are adequately prepared to integrate technology, digital-related phenomena, and digital media into their teaching practice (Manowaluilou et al., 2022). By incorporating digital literacy into teacher education programs (Peled, 2021), educational institutions can effectively assess pre-service teachers' progress and determine their proficiency using digital tools and resources. This evaluation process helps identify areas where further support or training may be needed to ensure that pre-service teachers have the necessary skills to succeed in their future classrooms.

Several difficulties have arisen when implementing digital assessment and evaluation, the continuous improvement of digital literacy skills, and the existing use of accountability within performance measurement tools among pre-service teachers' teaching practice of technology, learning approach integrated nature of digital literacy during internships. By scrutinizing assessment and evaluation, teacher educators benchmark the degrees of assessment and evaluation that contribute to the national contribution of determining the quantity and quality of the application of digital assessment.

4. Discussion

The discussion underscores the paramount importance of digital literacy in early childhood education and teacher preparation programs, emphasizing its profound impact on children's development and learning. However, a notable gap persists within Jordanian teacher education programs, where many novice educators lack the requisite technological proficiency to integrate digital tools into their classrooms effectively. Leveraging technologies like Big Data and AI could revolutionize student progression management, parental communication, and personalized learning experiences, highlighting the untapped potential of digital literacy skills. Despite recognition of its importance, practical integration of advanced technologies such as Big Data, AI, VR, and AR into teacher preparation programs remains lacking.

Addressing these challenges requires a comprehensive approach encompassing ethical considerations, digital safety, and engagement across diverse digitally mediated environments. By identifying essential competencies for pre-service teachers and crafting a model for competency development, this study aims to serve as a benchmark for teacher education institutes worldwide. Assessing and evaluating

teachers' digital literacy skills is crucial, with available tools supporting this process and contributing to the overall enhancement of digital literacy within the education system. Integrating digital literacy into early childhood education and teacher preparation programs is essential for preparing educators and students for success in the digital age, fostering innovation, and ensuring equitable access to digital resources and opportunities. Educational institution administrators and supervisors play a pivotal role in shaping teacher development curricula, ensuring they incorporate digital self-learning platforms like Massive Open Online Courses (MOOCs) to cater to the diverse needs of student teachers. Establishing professional learning communities within institutions fosters collaboration and support among educators, ultimately enhancing teaching effectiveness (Ihmeideh, 2014; Palaiologou, 2016).

Government agencies, private sectors, and teacher education institutions must prioritize funding and resource allocation to promote digital literacy and fluency within educational settings. By aligning with international standards and best practices, institutions can equip students and educators with essential digital skills necessary for the modern workforce (Baker and Siemens, 2014). Investment in developing learning resources, such as digital content and learning management systems, is vital for creating engaging and effective learning environments. Relevant regulatory bodies, such as the Teachers Council of Thailand, should take proactive steps to integrate digital literacy frameworks into teacher preparation programs. These frameworks should equip novice teachers with the skills to transition seamlessly from university to the workplace. Emphasis should be placed on promoting the sustainable integration of digital tools in teaching practices, aligning with broader educational goals such as the Sustainable Development Goals (Ihmeideh and Al-Khawalden, 2017). Educational institution administrators and supervisors can leverage e-training platforms to facilitate ongoing professional development for teachers. By providing access to a variety of modules tailored to individual needs, institutions empower educators to enhance their skills and stay updated on the latest developments in education technology (Krumsvik, 2014). Embracing e-training platforms can lead to more effective teaching practices and better student educational outcomes.

5. Conclusion

Digital literacy development is an educational concern and crucial for national development in the digital age. Both teachers and students must possess sufficient digital literacy to use technology effectively in education. The Cambridge Life Competencies Framework recognizes digital literacy as a critical competency for learners to participate effectively in the world and fulfill their potential. Developing these skills is crucial for students to adapt to the changing landscape of digital technologies and effectively engage with the online ecosystem.

The research findings underscore the direct impact of digital literacy on pedagogical methods, highlighting its positive influence on children's development. This emphasizes the importance of policy interventions in teacher education to mediate digital literacy and enhance teacher preparedness, addressing endogeneity concerns. The study's policy implications for promoting digital literacy and fluency in education are diverse. Firstly, government efforts should prioritize top-level design

and coordination, providing planning guidance and policy support for digital literacy and teacher education development. Secondly, initiatives should focus on constructing digital infrastructure, including establishing teacher education platforms and enhancing network synergy for digital literacy within the teacher education community. Creating a network among teacher education institutions is crucial to share best practices and leverage their collective expertise. Finally, ensuring that government efforts and contributions from various sectors are directed towards promoting digital literacy across all schools, regardless of size or subject taught, is essential for comprehensive implementation. Moreover, the study emphasizes the need for teacher education programs to prioritize conceptualizing digital literacy and fluency, integrating technology seamlessly into teaching practices, and transitioning from traditional content-centric approaches. This entails expediting the integration of digital literacy and fluency into teacher education, fostering an understanding of pedagogical and technological innovations, and establishing mechanisms for sharing digital resources among educational institutions. These efforts aim to create a cohesive approach to digitalization in education, addressing the challenge of meaningful digital engagement and enhancing overall teacher preparedness in the digital age.

5.1. Future research

Regularly assessing pre-service teachers' digital literacy progress throughout their teacher education program entails measuring changes in their knowledge, skills, attitudes, and confidence levels regarding digital technology use. This begins with an initial assessment of their digital literacy skills at the program's onset to establish a baseline. Subsequently, tracking the implementation of digital literacy interventions within the curriculum enables a thorough evaluation of their development. Advocating for integrating standardized frameworks into national and regional education policies ensures widespread adoption and sustained effectiveness.

5.2. Implications

To fortify the integration of digital technology in teacher education, a multifaceted strategy is imperative, transcending local contexts to offer actionable policy suggestions applicable across diverse educational landscapes and provide comprehensive support in promoting and disseminating learning materials on a large scale. Central to this approach is the seamless integration of digital literacy throughout teacher education curricula, necessitating specialized courses, hands-on experience with educational technologies, and continuous professional development for pre-service teachers. ANCOVA analysis has underscored the significance of factors such as years of education and hours of training in influencing digital literacy scores among pre-service teachers, emphasizing the need for tailored interventions in these areas. Additionally, fostering a collaborative culture among teacher educators encourages the exchange of best practices, enriching digital literacy development. Policymakers are pivotal in allocating resources and support for digital literacy initiatives, recognizing its transformative impact on educational outcomes. Collaborative efforts among stakeholders, spanning educational institutions, governmental bodies, and technology enterprises, are essential to cultivating an ecosystem conducive to digital

literacy development. By embracing these strategies, institutions and stakeholders worldwide can advance digital literacy in teacher education, ensuring educators are equipped to navigate the complexities of the digital age.

Author contributions: Conceptualization, NM and TT; methodology, NM; software, NM; validation, TT and NK; formal analysis, NM; investigation, NM, TT, PP, SU and NK; writing—original draft preparation, NM, TT, PP, SU and NK; writing—review and editing, NM; supervision, NK; project administration, NK; funding acquisition, NM. All authors have read and agreed to the published version of the manuscript.

Acknowledgments: We thank the Teacher Council of Thailand and the Faculty of Education Educational: Field Experience Center for their encouragement and valuable insights into teacher education preparation and policy. Additionally, we thank the administrators and deans of faculties of education across Thailand for their contributions to policy shaping and analysis.

Conflict of interest: The authors declare no conflict of interest.

References

Alelaimat, A. M., Ihmeideh, F. M., & Alkhawaldeh, M. F. (2020). Preparing Preservice Teachers for Technology and Digital Media Integration: Implications for Early Childhood Teacher Education Programs. International Journal of Early Childhood, 52(3), 299–317. https://doi.org/10.1007/s13158-020-00276-2

Althubyani, A. R. (2024). Digital Competence of Teachers and the Factors Affecting Their Competence Level: A Nationwide Mixed-Methods Study. Sustainability, 16(7), 2796. https://doi.org/10.3390/su16072796

Baker, R., & Siemens, G. (2014). Educational data mining and learning analytics. In: The Cambridge handbook of the learning sciences. UK Cambridge University Press. pp. 253–272. https://doi.org/0.1017/CBO9781139519526.016

Baydas, O., & Goktas, Y. (2016). Influential factors on pre-service teachers' intentions to use ICT in future lessons. Computers in Human Behavior, 56, 170–178. https://doi.org/10.1016/j.chb.2015.11.030

Bebell, D., & O'Dwyer, L. M. (2010). Educational Outcomes and Research from 1:1 Computing Settings. The Journal of Technology, Learning, and Assessment, 9(1).

Bitter, G., DeVoss, D., & Carpenter, J. (2019). Digital Literacies for Technical Communication: 21st Century Theory and Practice. Routledge.

Bolkan, S., & Goodboy, A. K. (2020). Understanding preservice teachers' technological pedagogical content knowledge: A latent profile analysis. Journal of Technology and Teacher Education, 28(2), 281–309.

Cervera, M. G., & Caena, F. (2022). Teachers' digital competence for global teacher education. European Journal of Teacher Education, 45(4), 451–455. https://doi.org/10.1080/02619768.2022.2135855

Crompton, H., Burke, D., Gregory, K. H., & Gräbe, C. (2021). The DigCompEdu Framework: Assessing Teachers' Digital Competence and Professional Development Needs. Springer.

Falagas, M. E., Pitsouni, E. I. Malietzis, G. A., & Pappas, G. (2008). Comparison of PubMed, Scopus, Web of Science, and Google Scholar: StrenghtsStrengths and weaknesses. The FASEB Journal, 22(2), 338–342. https://doi.org/10.1096/fj.07-9492lsf

Falloon, G. (2020). From digital literacy to digital competence: the teacher digital competency (TDC) framework. Education Technology Research and Development, 68, 2449–2472. https://doi.org/10.1007/s11423-020-09767-4

Fister, B. (2018). Economic Development and Entrepreneurship in Transition Economies: Issues, Obstacles and Perspectives. Routledge.

Fraillon, J., Ainley, J., Schulz, W., et al. (2019). Preparing for Life in a Digital World: IEA International Computer and Information Literacy Study 2018 International Report. Springer.

Geir, O., Marijana, K., & Gréta, G. (2014). Professional digital competence in teacher education. Nordic Journal of Digital Literacy, 9(4), 243–249. https://doi.org/10.18261/issn1891-943x-2014-04-02

Gough, D., Oliver, J. & Thomas, S. (2012). Clarifying differences between review designs and methods. Systematic Review, 1(1), 28. https://doi.org/10.1186/2046-4053-1-28

Haleem, A., Javaid, M., Qadri, M. A., & Suman, R. (2022). Understanding the role of digital technologies in education: A review. Sustainable Operations and Computers, 3, 275–285. https://doi.org/10.1016/j.susoc.2022.05.004

Hazzam J., & Wilkins, S. (2023). The influences of lecturer charismatic leadership and technology use on student online engagement, learning performance, and satisfaction. Computers & Education, 20, 2023 104809. https://doi.org/10.1016/j.compedu.2023.104809

Hsieh, H. F., & Shannon, S. E. (2005). Three Approaches to Qualitative Content Analysis. Qualitative Health Research, 15(9), 1277–1288. https://doi.org/10.1177/1049732305276687

Huang, F., Teo, T., & Zhou, M. (2019). Factors Affecting Chinese English as a Foreign Language Teachers' Technology Acceptance: A Qualitative Study. Journal of Educational Computing Research, 57(1), 83–105. https://doi.org/10.1177/0735633117746168

Ihmeideh, F. M. (2014). The effect of electronic books on enhancing emergent literacy skills of pre-school children. Computers & Education, 79, 40–48. https://doi.org/10.1016/j.compedu.2014.07.008

Ihmeideh, F., & Al-Khawaldeh, M. (2017). Teachers' and parents' perceptions of the role of technology and digital media in developing child culture in the early years. Children and Youth Services Review, 77(52), 139–146. https://doi.org/10.1016/j.childyouth.2017.04.013

Instefjord, E., & Munthe, E. (2016). Preparing pre-service teachers to integrate technology: An analysis of the emphasis on digital competence in teacher education curricula. European Journal of Teacher Education, 39(1), 77–93. https://doi.org/10.1080/02619768.2015.1100602

Johnson, D. S., & Lee, K. R. (2022). Teacher Professional Development in the Digital Era. Teacher Education Journal, 30(1), 65–80.

José, M., Marta, M., José, F., & Inmaculada, G. (2020). Digital competences for teacher professional development Systematic review. European Journal of Teacher Education, 45(4), 513–531. https://doi.org/10.1080/02619768.2020.1827389

Krumsvik, R. (2014). Teacher educators' digital competence. Scandinavian Journal of Educational Research, 58(3), 269–280. https://doi.org/10.1080/00313831.2012.726273

Lei, J. (2009). Digital natives as Pre-service teachers: What technology preparation is needed? Journal of Computing in Teacher Education, 25(3), 87–97. https://doi.org/10.1093/jahist/jaq049

Liang, J.-C., & Hwang, G.-J. (2023). A robot-based digital storytelling approach to enhancing EFL learners' multimodel storytelling ability and narrative engagement. Computers & Education, 201, 1–24. https://doi.org/10.1016/j.compedu.2023.104827

Liberati, A., Altman, D., Tetzlaff, J. M., et al. (2009). The PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of Studies That Evaluate Health Care Interventions: Explanation and Elaboration. Journal of Clinical Epidemiology, 62(10), e1–e34. https://doi.org/10.1016/j.jclinepi.2009.06.006

Madalińska-Michalak, J., Barker, R. M., & Cooper, G. (2018). Professional competencies and standards in teacher education. International Journal of Educational Research, 87, 12–19.

Manowaluilou, N. (2020). Development of open educational resources for supporting academic English in higher education. Kasetsart Journal of Social Sciences, 41(2), 238–243.

Manowaluilou, N., & Reeve, E. (2022). Pre-service teachers' self-efficacy support systems resulting in a desire to become teachers. International Education Studies, 15(2), 41–53. https://doi.org/10.5539/ies.v15n2p41

Manowaluilou, N., Butkatunyoo, O., & Mahavijit, P. (2022). Phenomenon-based teaching competency development for teacher educators in higher education in Thailand. Kasetsart Journal of Social Sciences, 43, 727–734. https://doi.org/10.34044/j.kjss.2022.43.3.26

Manowaluilou, N., Nilsook, P., & Buasuwan, P. (2020). Perceptions and the new paradigm of Thai vocational education. International Journal of Innovation and Learning, 33(3), 344–365. https://doi.org/10.1504/ijil.2023.130101

Masenya, T. M. (2021). Digital Literacy Skills as Prerequisite for Teaching and Learning in Higher Education Institutions. Mousaion: South African Journal of Information Studies, 39(2), https://doi.org/10.25159/2663-659X/8428

Neumann, K. L., Alvarado-Altertorio, F., & Ramírez-Salgado, A. (2021). Aligning with Practice: Examining the Effects of a Practice-Based Educational Technology Course on Preservice Teachers' Potential to Teach with Technology. TechTrends, 65(4). https://doi.org/10.1007/s11528-021-00672-y

Nguyen, L.A.T., & Habók, A. (2023). Tools for assessing teacher digital literacy: A review. Journal of Computers in Education. https://doi.org/10.1007/s40692-022-00257-5

Ozkan-Ozen, Y., & Kazancoglu, Y. (2021). Digital literacy skills: A systematic review and framework proposal. Computers & Education, 161, 104090.

Palaiologou, L. (2016). Teachers' dispositions towards the role of digital devices in play-based pedagogy in early childhood education. Early Years, 36(3), 305–321. https://doi.org/10.1080/09575146.2016.1174816

Peled, Y. (2021). Pre-service teacher's self-perception of digital literacy: The case of Israel. Education and Information Technologies, 26. 2879–2896. https://doi.org/10.1007/s10639-020-10387-x

Peromingo, M., & Pieterson, W. (2018). The new world of work and the need for digital empowerment. Forced Migration Review, 58, 32–33.

Petticrew, M., & Roberts, H. (2006). Systematic Reviews in the Social Sciences: A Practical Guide. Wiley-Blackwell. https://doi.org/10.1002/9780470754887

Ramanau, R., & Geng, F. (2021). Exploring students' digital literacy practices beyond higher education: Findings from the international computer and information literacy study (ICILS) 2018. Computers & Education, 168, 104213.

Saldana, J. (2015). The Coding Manual for Qualitative Researchers. Newcastle upon Tyne: Sage.

Spante, M., Hashemi, S. S., Ludin, M., & Algers, A. (2018). Digital competence and digital literacy in higher education research: Systematic review of concept use. Cogent Education, 5(1), 1–21.

Tinmaz, H., Lee, Y.T., Fanea-Ivanovici, M., & Baber, H. (2022). A systematic review on digital literacy. Smart Learning Environments, 9(21). https://doi.org/10.1186/s40561-022-00204-y

Tondeur, J., van Braak, J., Guoyuan, S., et al. (2012). Preparing pre-service teachers to integrate technology in education: A synthesis of qualitative evidence. Computers & Education, 59(1), 1–11. https://doi.org/10.1016/j.compedu.2011.10.009

Valtonen, T., Sointu, E., Kukkonen, J., & Mäkitalo, K. (2015). Developing a TPACK measurement instrument for 21st century pre-service teachers. Seminar.net International Journal of Media, Technology & Lifelong Learning, 11(2), 86–100. https://doi.org/10.7577/seminar.2353

van Laar, E., van Deursen, A. J. A. M., van Dijk, J. A. G. M., & de Haan, J. (2017). The relation between 21st-century skills and digital skills: A systematic literature review. Computer in Human Behavior, 72, 577–588. https://doi.org/10.1016/j.chb.2017.03.010

Wu, X., & Li, J. (2023). Becoming competent global educators: Pre-service teachers' global engagement and critical examination of human capital discourse in globalized contexts. International Journal Educational Research, 119, 102181. https://doi.org/10.1016/j.ijer.2023.102181