

Integrating Digital Competencies into Early Childhood Education: Research at Hai Duong University

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This article examines the integration of digital competencies into early childhood education programs from the perspectives of lecturers, researchers, and educators at Hai Duong University, Vietnam. Based on a survey of 395 students and quasi-experimental interventions in two courses—*Hygiene and Nutrition for Preschool Children* and *Disease Prevention and Child Safety*—the study employed a digital competence scale, product assessment rubrics, and SPSS statistical tools to validate the effectiveness of the intervention. Findings reveal that prior to the experiment, most students demonstrated only basic levels of competence, with significant limitations in applying artificial intelligence (AI). After integration, students' digital competence improved markedly across all five dimensions, with AI-related skills showing the greatest increase. Reliability and validity of the measurement scale were confirmed through Cronbach's Alpha, EFA, and CFA, while paired samples t-tests and Cohen's d indicated statistically significant differences with medium to large effect sizes. The study affirms the feasibility of embedding digital competencies into early childhood teacher education and recommends innovations in pedagogical approaches and enhanced awareness of digital ethics, thereby equipping future teachers with the capacity to apply technology safely, creatively, and effectively.

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Keywords: Digital competence, early childhood education, curriculum integration, educational technology, digital transformation in education.

Introduction

In the context of the Fourth Industrial Revolution, digital competence has emerged as one of the core skills required of 21st-century citizens, necessitating its development from the earliest stages of education. As technology increasingly permeates daily life, equipping young children with foundational knowledge and skills in digital technologies has become an inevitable trend, preparing future generations for adaptability and creativity in a knowledge-based society. International organizations such as UNESCO (2021) and the European Commission (2019) have emphasized digital competence as an indispensable component of modern education programs.

While the integration of technology into general education has received significant policy and practical attention, its application in early childhood education remains relatively novel, especially in developing countries. This is largely due to the unique requirements of preschool-aged children—a period characterized by rapid cognitive, emotional, and physical development, where direct interaction with real-life experiences is prioritized over screen-based engagement. Nevertheless, recent studies indicate that when intentionally designed and implemented by qualified educators, technology-enhanced educational activities can positively contribute to the holistic development of young children (NAEYC & Fred Rogers Center, 2012).

In Vietnam, the Ministry of Education and Training has issued a Digital Competency Framework for learners (Circular 02/2025/TT-BGDĐT), which includes the competency of using artificial intelligence (AI) as a core skill. However, empirical studies on integrating digital competencies into preschool teacher education programs remain limited, particularly regarding pedagogical activities that support AI and assessment models for future teachers. Hai Duong University has implemented initial activities to integrate educational technology content into the Early Childhood Education training program. The goal is not only to enhance the professional competencies of pedagogy

students but also to help shape children's future digital competencies through a cohort of well-trained teachers.

This article analyzes the integration of digital competencies into the ECE curriculum at Hai Duong University, Vietnam. Drawing upon curriculum analysis, student surveys, and lecturer interviews, the study identifies the current situation, challenges, and suitable approaches within the context of educational digital transformation. In doing so, the article contributes to both academic and practical discussions on technology in early childhood education, particularly from the perspective of teacher education institutions in developing contexts.

To clarify the above issues, the study addresses the following research questions: In what forms and to what extent are digital competencies—particularly artificial intelligence (AI) applications—currently integrated into early childhood teacher education programs? How do lecturers and students perceive and demonstrate readiness for integrating digital competencies, as reflected in empirical surveys? What advantages, challenges, and solutions influence the effectiveness of integrating digital competencies into teacher education at the institution?

Literature Review

Concept of Digital Competence

Digital competence is understood as a set of knowledge, skills, and attitudes that enables individuals to use digital technologies effectively, safely, responsibly, and creatively in order to achieve learning, professional, and personal development goals (European Commission, 2022). According to the European Commission, digital competence goes beyond the ability to operate devices or software; it also encompasses information processing, online communication and collaboration, content creation, digital safety, problem-solving, and understanding of emerging technologies such as artificial intelligence (AI) (Redecker, 2017).

In the context of rapid digital transformation, “digital competence” has become a key concept

of growing interest to international organizations and researchers. UNESCO (2018) emphasizes that digital competence extends beyond the mere use of technology; it involves the ability to access, manage, evaluate, communicate, and create information safely for purposes of learning, employment, and entrepreneurship. Since the 1990s, Gilster (1997) laid the foundation for this concept by asserting that *digital literacy* is “the mastery of ideas” rather than simply technical computer skills. Globally, the European Council’s DigComp framework identifies five core areas of competence: information processing, communication, content creation, digital safety, and problem-solving (Carretero et al., 2017). Similarly, some universities have developed their own digital competence frameworks. For example, in Vietnam, the Vietnam National University (VNU) collaborated with Meta to design a framework with seven domains, ranging from device operation and data utilization to online communication and lifelong career skills development (Nguyen & Le, 2022). Collectively, these definitions and frameworks demonstrate that digital competence today is not limited to technical expertise but also entails critical thinking, creativity, and social responsibility in digital environments (Tang & Chaw, 2016; Chan et al., 2017).

According to Popenici and Kerr (2017), AI can be defined as computer systems capable of performing human-like processes such as learning, adapting, synthesizing, self-correcting, and using data to handle complex tasks. Purdy and Daugherty (2016) further describe AI as a collection of technologies that can be combined in multiple ways to perceive, interpret, and act, based on the ability to learn from experience and adapt. Within AI, machine learning (ML) is considered a subset, referring to software capable of recognizing patterns, making predictions, and applying these patterns to situations beyond the original scope of design (Popenici & Kerr, 2017).

In Vietnam, to meet the requirements of digital transformation in education and training, the Ministry of Education and Training issued Circular No. 02/2025/TT-BGDĐT on January 24, 2025, establishing a digital competence framework for learners, effective from March 11, 2025. This framework aims to standardize the knowledge, skills, and attitudes necessary in digital environments, ensuring consistency in curriculum design, competence assessment, and human resource development in line with the Fourth Industrial Revolution. The framework comprises six major domains and 24 component competencies, organized into four proficiency levels ranging from basic to advanced, and aligned with eight competence levels.

Table 1. The Digital Competence Framework for Learners (MOET, 2025)

Competence Domain	Main Content	Representative Sub-Competencies
Data and Information Literacy	Identifying, searching, evaluating, organizing, and using digital information effectively	Searching for information, evaluating sources, managing personal data
Digital Communication and Collaboration	Interacting and working in online groups; managing digital identity; respecting cultural diversity	Online meetings, collaboration through digital platforms, building a safe digital profile
Digital Content Creation	Creating, editing, and sharing content; addressing copyright issues; basic programming	Designing digital resources, using multimedia, complying with copyright
Digital Safety	Protecting data and devices; ensuring psychological and physical well-being; maintaining a safe digital environment	Password management, cybersecurity, digital hygiene

Problem-Solving with Technology	Applying technology to address challenges; developing critical and creative thinking	Troubleshooting technical issues, analyzing and optimizing solutions
Artificial Intelligence (AI) Literacy	Understanding, evaluating, and using AI transparently and responsibly; recognizing ethical and social implications	AI-based searching, AI-generated content creation, AI risk assessment

This structure aligns with the European DigComp framework and the DigCompEdu framework for teachers, both of which emphasize the development of competencies in information retrieval and processing, digital communication, content creation, and problem-solving within digital environments (Redecker, 2017).

In sum, digital competence is a comprehensive concept encompassing both technical and cognitive dimensions. It serves as a foundational capacity that equips learners to adapt to the rapid pace of technological change and the evolving demands of the digital workplace in the twenty-first century.

The Role of Digital Competence in Early Childhood Teacher Education and Professional Practice

In early childhood teacher education, digital competence plays a crucial role in renewing teaching methods, designing digital learning materials, and organizing technology-integrated educational activities. Preservice early childhood education (ECE) students who are equipped with digital skills are able to exploit digital resources (e.g., images, videos, educational games), use lesson-design software, and apply online tools to make learning activities more engaging and interactive (Nguyễn Thị Thanh & Trần Thị Mỹ Linh, 2023). Moreover, digital competence helps students cultivate habits of working in digital environments, improve their capacity for online collaboration, and prepare themselves for the digital transformation requirements of the education sector.

ECE holds a foundational position in the national education system, laying the first building blocks for holistic child development across physical,

cognitive, linguistic, socio-emotional, and aesthetic domains. A hallmark of early childhood education is its child-centered approach, with a strong focus on hands-on experiences, physical activity, social interaction, and integrated play-based learning. In the digital era, integrating technology into ECE presents unique pedagogical and ethical challenges while also creating opportunities for innovation.

Within the context of educational digital transformation, digital competence has become one of the core criteria in teacher training. Equipping preservice students with digital skills not only enhances their access to knowledge through electronic resources but also strengthens their ability to design digital lessons, create online learning games, and apply innovative teaching methods (Instefjord & Munthe, 2017; Redecker, 2017). Digital competence also fosters critical thinking, problem-solving, and adaptability to modern educational environments (Ilomäki et al., 2016). Research by Nguyễn Thị Thanh & Trần Thị Mỹ Linh (2023) similarly highlighted that strong digital skills enable ECE students to design visually engaging activities and use software and online tools to support children's effective learning.

Đặng Văn Em and colleagues (2024) analyzed the use of ChatGPT by 584 students at Vietnam National University Ho Chi Minh City in the context of learning and research, highlighting its positive aspects when used effectively. To maximize the potential of ChatGPT responsibly, their study recommended that students evaluate the authenticity of information sources, cross-check across multiple references, and develop essential skills such as asking precise, intelligent questions to obtain accurate and comprehensive

information. They also stressed the importance of language and grammar awareness to optimize interaction. Understanding how to use ChatGPT effectively can help students complete tasks with greater efficiency; however, it cannot replace human creativity, knowledge construction, or the development of new ideas. Learning and research remain creative processes that involve personal experience and independent thinking. Therefore, students should use ChatGPT as a valuable support tool while maintaining independent thought and creativity. The study also emphasized the role of educational administrators in setting objectives, managing data, safeguarding privacy, and defining the responsibilities of both lecturers and students in using ChatGPT.

When entering the profession, digitally competent preschool teachers can readily integrate technology into classroom management, maintain child development portfolios using learning management systems (LMS) or specialized software, and connect with parents through digital platforms (Voogt et al., 2015). UNESCO (2023) also stressed that digital

competence enables ECE teachers to keep pace with new educational models and participate in online professional learning communities, thereby improving the quality of child care and education.

In professional practice, preschool teachers with strong digital skills can design and deliver multimedia learning activities, integrate technology into classroom management, track children's progress through electronic portfolios, and maintain effective parent-teacher communication (Cabero-Almenara et al., 2021). In addition, digital competence opens opportunities for continuous professional development through open online courses and participation in international professional communities (Krumsvik, 2011). This indicates that digital competence not only enhances the quality of teaching but also broadens professional horizons, helping preschool teachers align with global educational trends.

A summary table below outlines the roles of digital competence across two key stages: preservice education and professional practice as an ECE teacher.

Table 2. Roles of Digital Competence in Preservice Education and Professional Practice

Stage	Main Roles	Illustrative Examples
During Preservice Education	- Exploit digital learning resources and open educational resources (OER). - Design digital lessons and technology-integrated educational activities. - Use online tools to organize interactive learning activities. - Develop digital communication and collaboration skills. - Cultivate critical thinking and problem-solving abilities.	- Use Canva, PowerPoint, or Genially to design activities. - Search for educational resources on OER Commons. - Organize educational games via Kahoot or Quizizz.
In Professional Practice	- Apply technology to classroom management and child development portfolios. - Use specialized preschool management software (e.g., KidsOnline, MầmNon24h). - Maintain effective communication with parents through digital platforms. - Participate in online professional learning communities to share experiences. - Utilize artificial intelligence to optimize educational planning and personalize learning activities.	- Record and track child development using LMS. - Communicate with parents via Zalo, Facebook, or dedicated applications. - Use ChatGPT or other AI tools to generate ideas for educational activities.

Integration of Digital Competence in Early Childhood Teacher Education Programs

Within the context of educational digital transformation, integrating digital competence into early childhood teacher education programs has become an essential requirement. Research indicates that when digital skills are embedded into pedagogical courses, students not only practice designing electronic lesson plans and organizing digital learning games but also develop creativity and problem-solving abilities (Instefjord & Munthe, 2017; Redecker, 2017). In addition, dedicated courses on educational technology in early childhood education provide students with core knowledge and skills in managing digital learning resources, digital safety, and online communication (Cabero-Almenara, Romero-Tena, & Palacios-Rodríguez, 2021). Scholars argue that embedding digital competence not only modernizes teacher training curricula but also equips future preschool teachers with the ability to adapt to the professional innovations of the digital era (Ilomäki, Paavola, Lakkala, & Kantosalo, 2016).

Masoumi (2025) emphasizes that teacher education programs must design approaches to developing professional digital competence from the early practicum stage. Similarly, Su and Yang (2023) highlight through a systematic review that most studies underscore the importance of clearly defining digital competence for early childhood teachers as a basis for designing targeted training programs. Dolezal (2025) further argues for systematic integration across theoretical and practical courses to prevent a lack of readiness when graduates begin teaching. De Rossi and Ferranti (2025) advocate for developing innovative digital competence through education communities, emphasizing continuous professional development in the ECE context. In this sense, the integration of digital competence in ECE teacher education not only enables students to master technology but also supports the construction of digital pedagogies aligned with real-world requirements, thereby enhancing autonomy and creativity in child education.

The European DigComp framework for citizens and the DigCompEdu framework for teachers (European Commission, 2019) outline core competencies such as information access, digital communication, content creation, digital safety, and problem-solving in technological environments. In ECE contexts, these competencies must be tailored in scope and level, focusing on enabling children to engage with technology safely, interact positively, and establish learning habits in digital environments under the guidance of teachers.

The Technological Pedagogical Content Knowledge (TPACK) model (Mishra & Koehler, 2006) plays a central role in teacher education, particularly for ECE students. This model highlights the intersection of three domains—content knowledge, pedagogical knowledge, and technological knowledge—thereby enabling teachers to select, integrate, and apply technology effectively in ways that align with children's developmental goals. In Vietnam, TPACK can be incorporated into pedagogical methodology courses to enhance students' ability to design lessons that integrate technology.

Although Vietnam's revised Early Childhood Education Curriculum (2021) does not explicitly designate digital competence as an independent developmental domain, it has created pedagogical spaces that integrate technology into areas such as cognition, language, socio-emotional development, and aesthetics. This provides favorable conditions for teacher education institutions, including Hai Duong University, to embed educational technology into the ECE program, aiming to develop digitally minded preschool teachers capable of responding to the demands of educational digital transformation. Integrating digital competence into ECE teacher training must be carried out systematically to ensure that students not only acquire disciplinary knowledge and skills but also apply digital technologies effectively in practice. According to the OECD (2023), the most effective approach is embedded integration, in which digital competence is incorporated across multiple courses and professional experiences rather than being confined to standalone ICT modules.

We illustrate below how the five domains of digital competence can be integrated into selected representative courses, along with specific activities that enable students to practice skills while cultivating responsibility and ethical

awareness in applying technology to child care and education. At institutions such as Hai Duong University, integration can be implemented through the following approaches:

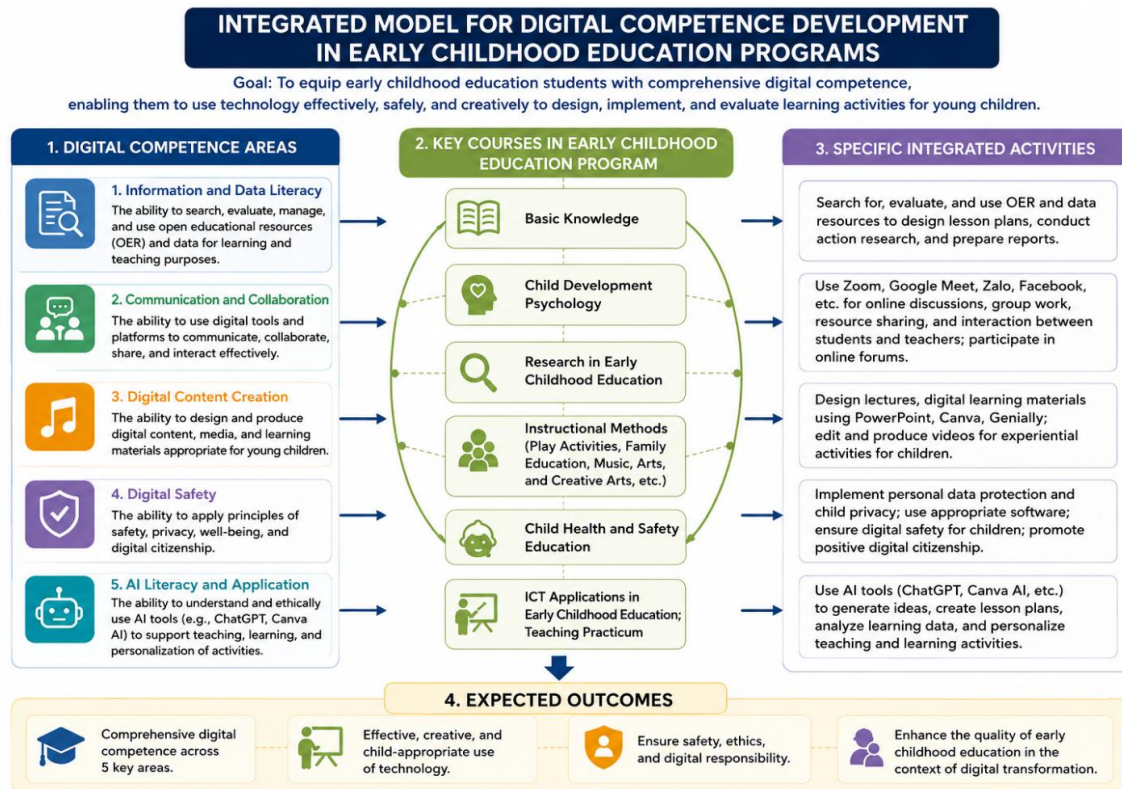


Figure 1. Integrated model of digital competence in early childhood teacher education programs

Research Methodology

Research Objectives

The study was designed as a quasi-experimental intervention, employing a pre-test–post-test approach within a single group of students, with recommendations to include a control group if conditions permit. The research participants consisted of college-level Early Childhood Education (ECE) students enrolled in two courses: *Hygiene and Nutrition for Preschool Children* and *Disease Prevention and Safety for Preschool Children*.

Each course carried 2 credits and was structured with 15 theoretical sessions, 15 discussion–practice sessions, and 70 hours of self-study. The selection of these two courses was based on their close alignment with the component competencies specified in Domain 6 of the Digital Competence Framework for Learners,

particularly the ability to understand, responsibly use, and critically evaluate artificial intelligence (AI) tools.

Integration and Implementation Process

In the course *Hygiene and Nutrition for Preschool Children*, the content of Chapter 3 (*Nutrition for Children*) and Chapter 4 (*Integrated Approaches to Nutrition Education*) was selected for AI-based integration. Students were guided to use AI tools to design age-appropriate meal plans and menus, as well as to create educational games or digital materials on nutrition. These activities were directly linked to competencies 6.1 (AI literacy), 6.2 (responsible AI use), and 6.3 (AI tool evaluation).

In the course *Disease Prevention and Safety for Preschool Children*, the integration focused on Chapters 2 and 4 (*Common and Infectious Diseases*) together with Chapters 6 and 7 (*Safety, First Aid*,

and Preventive Education). Here, students applied AI to simulate disease scenarios, design hypothetical accident cases, and produce communication materials on disease prevention and safety for parents.

Instrument Design and Assessment Objectives

To measure effectiveness, the research team developed an AI competence scale comprising three components aligned with Domain 6 of the Digital Competence Framework: AI literacy, responsible AI use, and AI tool evaluation. Each component included between four and eight items rated on a five-point Likert scale.

In addition, a product assessment rubric was designed specifically for each course. For the *Hygiene and Nutrition* course, the rubric emphasized nutritional accuracy, educational value, responsible use of AI, and pedagogical presentation. For the *Disease Prevention and Safety* course, the rubric focused on basic medical accuracy, safety and first aid, ethical responsibility in AI use, and communication effectiveness.

Furthermore, the study employed a shortened version of the Technology Acceptance Model (TAM) scale with two components—perceived usefulness and perceived ease of use—in order to examine students' attitudes toward AI integration.

Research Procedure

The study was conducted in three phases. The first phase, the pre-test, involved assessing students' baseline AI competence, surveying their attitudes toward technology acceptance, and administering a prior-knowledge test for the course.

The second phase consisted of the intervention, during which instructors integrated two to three AI-based learning activities into the selected chapters. These activities emphasized ethical considerations, responsible use, and information verification.

The final phase, the post-test, included reassessment of AI competence, technology acceptance attitudes, course knowledge, and evaluation of student products using the established rubrics. In addition to quantitative measures, the research team conducted focus group discussions to gather qualitative insights into the feasibility and challenges of applying AI in the learning process.

Research Results

Integration of Digital Competence into the Early Childhood Education Curriculum

The integration of digital competencies into the Early Childhood Education (ECE) curriculum at Hai Duong University is built on the Digital Competency Framework for learners issued by the Ministry of Education and Training (MOET, 2025). This model uses an embedded integration approach, in which digital competencies are incorporated into two specialized courses: Hygiene and Nutrition for Young Children and Disease Prevention – Ensuring Safety for Young Children.

The integration focuses on five areas of digital competency: digital information skills, digital communication and collaboration, digital content creation, digital safety and ethics, and knowledge of artificial intelligence (AI). Through AI-supported learning, collaborative activities, multimedia design, and case-based learning, students are guided to apply digital technologies in real pedagogical contexts. In both courses, students use digital and AI tools to search for information, design educational materials, simulate safety scenarios, analyze learning data, and create child-centered digital learning activities.

This integration model aims to enhance students' professional digital competencies, promote the responsible and ethical use of technology, and prepare future early childhood teachers to meet the demands of digital transformation in education.

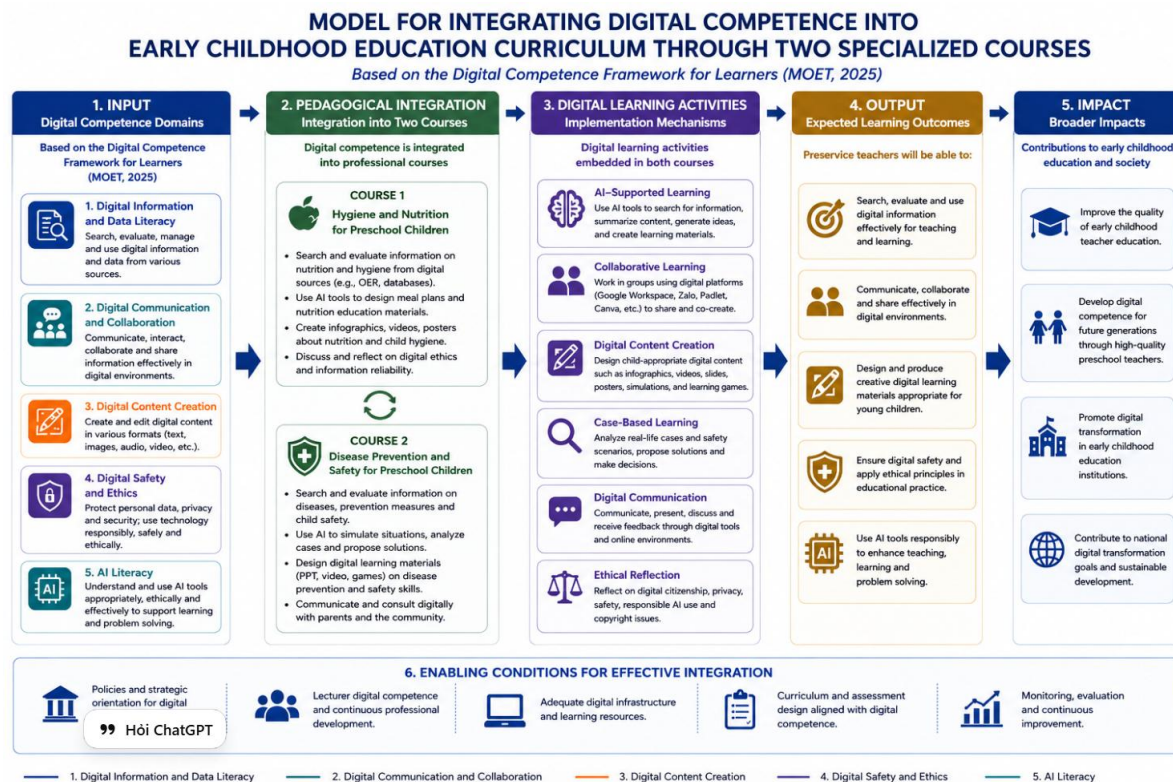


Figure 2. Model for Integrating Digital Competence into Early Childhood Teacher Education through Two Specialized Courses

Rubric for Assessing Digital Competence in Early Childhood Education Programs

In the current educational context, integrating digital competence into early childhood teacher education programs has become an urgent requirement to prepare students for adapting to the rapid pace of technological change. In particular, the Ministry of Education and Training has issued the Digital Competence Framework for Learners, in which Domain 6 emphasizes competencies related to artificial intelligence (AI), consisting of three components: AI literacy, responsible AI use, and AI tool evaluation.

To operationalize this framework within teacher education, the development of a digital competence assessment rubric serves not only as a tool for lecturers and students to measure achievement levels but also as a foundation for designing and adjusting learning activities in a competence-based orientation. Such a rubric further contributes to bridging program objectives, learning outcomes, and the practical application of digital technologies in child care and education. It ensures that students are not only capable of using digital tools but are also able to critically evaluate, creatively apply, and responsibly integrate them in safe, ethical, and effective ways.

Table 3. Rubric for Assessing Digital Competence in Early Childhood Teacher Education

Criteria / Sub-Competency	Basic	Intermediate	Advanced	Proficient
Digital Literacy & Information	Able to conduct basic searches and identify	Conducts multi-source searches and filters biased information.	Analyzes, compares, and accurately cites digital sources.	Evaluates and synthesizes complex information; guides others in digital information use.

	reliable sources.			
Digital Communication & Collaboration	Uses email, Zalo, or LMS for academic exchanges.	Participates effectively in online learning groups.	Manages and organizes online group activities.	Designs and leads collaborative digital projects for colleagues.
Digital Safety & Ethics	Maintains passwords; identifies basic digital risks.	Protects personal data and avoids misinformation.	Practices digital safety in teaching; demonstrates ethical awareness.	Provides consultation; develops ethical guidelines for colleagues and children.
Digital Content Creation	Creates simple learning materials using PowerPoint.	Uses digital tools to design assignments and educational games.	Designs interactive digital learning resources with integrated visuals, audio, and video.	Develops comprehensive digital learning packages/programs with scalability and sharing capacity.
Artificial Intelligence (AI) Literacy	Recognizes AI and uses basic AI tools (e.g., translation, search).	Applies AI tools to design preschool learning activities and verify results.	Creates digital content with AI (e.g., drawings, stories, scripts) and critically analyzes limitations and reliability.	Evaluates AI applications in terms of transparency, fairness, and safety; proposes models for applying AI in early childhood education.

Pre-Intervention Status in the Course

Before integrating digital competence into the selected courses, the research team surveyed 395 Early Childhood Education students using the

Digital Competence Rubric. The results revealed that the majority of students remained at the *Basic* level, only a small number reached the *Advanced* level, and none achieved the *Proficient* level.

Table 4. Pre-Intervention Digital Competence Levels of ECE Students (n = 395)

Criteria / Sub-Competency	Evaluation level							
	Basic		Intermediate		Advanced		Proficient	
	Quantity	percentage	Quantity	percentage	Quantity	percentage	Quantity	percentage
Digital Literacy & Information	198	50	148	37	49	13	0	0
Digital Communication & Collaboration	210	53	142	36	43	11	0	0

Digital Safety & Ethics	221	56	135	34	39	10	0	0
Digital Content Creation	225	57	132	33	38	10	0	0
Artificial Intelligence (AI) Literacy	237	60	130	33	28	7	0	0

The survey results indicate that students' digital competence prior to the intervention was generally limited. Across all five rubric criteria, the majority of students achieved only the *Basic* level (50–60%), while the proportion at the *Intermediate* level ranged from approximately 30% to 37%. Only a small number of students (7–13%) reached the *Advanced* level, and none attained the *Proficient* level. This suggests that most students possessed only fundamental skills, such as conducting simple information searches, using common online communication tools, creating basic teaching materials, and recognizing a few principles of digital safety.

Among the five criteria, Artificial Intelligence (AI) applications emerged as the weakest competence. As many as 60% of students remained at the *Basic* level and 33% at the *Intermediate* level. Their knowledge of AI was largely confined to using it as a tool for translation or information searches, with little ability to employ it responsibly or to evaluate the accuracy, transparency, and ethical implications of AI-generated outputs. These results

demonstrate that students have not yet met the requirements outlined in the Ministry of Education and Training's Digital Competence Framework, particularly in the domains of digital content creation and responsible AI use. This provides crucial empirical evidence for the implementation of digital competence integration into ECE courses, aiming to enhance students' comprehensive digital skills in the context of educational digital transformation.

Post-Intervention Results in the Course

To assess the reliability of the measurement scale after the experimental intervention, the study conducted Cronbach's Alpha testing with five observed variables (TN1–TN5). The results indicated a Cronbach's Alpha coefficient of 0.790, exceeding the threshold of 0.70. This demonstrates that the scale achieved acceptable reliability and was suitable for subsequent analyses. The corrected item–total correlations ranged from 0.493 to 0.649, all above the 0.30 benchmark, confirming that the items were strongly correlated with the overall scale.

Table 5. Level Reliability Analysis (Cronbach's Alpha if Item Deleted)

Item	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item–Total Correlation	Cronbach's Alpha if Item Deleted
Digital Literacy & Information	14.61	9.152	0.594	0.743
Digital Communication & Collaboration	14.59	9.248	0.649	0.725
Digital Safety & Ethics	14.56	10.266	0.493	0.774

Digital Content Creation	14.58	9.624	0.551	0.757
Artificial Intelligence (AI) Literacy	14.60	9.858	0.560	0.754

In addition, if any single observed variable were removed, the Cronbach's Alpha coefficient ranged only from 0.725 to 0.774, which was not substantially higher than the overall coefficient. This indicates that all five variables (TN1–TN5) were appropriate and should be retained in the scale. Thus, the post-intervention Cronbach's Alpha results confirmed that the digital competence scale demonstrated both stability and strong reliability, meeting the requirements for subsequent factor analyses (EFA/CFA) and further statistical tests.

To validate the structure and construct validity of the digital competence scale—developed on the basis of the five-criterion rubric (digital knowledge and information, digital communication and collaboration, digital safety and ethics, digital content creation, and artificial intelligence applications)—the study employed exploratory factor analysis (EFA) and

confirmatory factor analysis (CFA). EFA was first conducted to examine the convergence of observed variables into latent factors according to the theoretical framework. The results showed that all observed variables had acceptable factor loadings (> 0.4), were organized into five groups consistent with the rubric structure, and explained the majority of data variance. Subsequently, CFA was carried out to evaluate the model fit of the five-factor structure with the experimental data. The model fit indices (CFI, TLI, RMSEA, etc.) all met acceptable thresholds, while both convergent and discriminant validity were confirmed, indicating that the scale possessed high reliability and validity.

Overall, these findings suggest that the integration of digital competence into the training program is not only feasible in practice but also scientifically validated through factor analyses.

Table 6. Factor Loadings of Observed Variables

Factors	Observation variables	Factor Loadings
Digital Literacy & Information	LD1 (0.762), LD2 (0.724), LD3 (0.760), LD4 (0.793), LD6 (0.720), LD5 (0.475)	0.47 – 0.79
Digital Communication & Collaboration	DT1 (0.763), DT2 (0.672), DT3 (0.782), DT4 (0.802), DT5 (0.783)	0.67 – 0.80
Digital Safety & Ethics	CV1 (0.743), CV2 (0.778), CV3 (0.757), CV4 (0.799), CV5 (0.745)	0.74 – 0.80
Digital Content Creation	DK1 (0.749), DK2 (0.775), DK3 (0.730), DK4 (0.672), DN4 (0.612)	0.61 – 0.78
Artificial Intelligence (AI) Literacy	TL1 (0.744), TL2 (0.738), TL3 (0.742), TL4 (0.746), DN1 (0.737), DN2 (0.740), DN3 (0.753)	0.73 – 0.75

After identifying the five-factor structure through EFA, the study proceeded with confirmatory factor analysis (CFA) to test the theoretical

model's fit with the empirical data. The CFA results showed that all indices met the acceptable thresholds: Chi-square/df = 2.08 (< 3.0), CFI =

0.934, TLI = 0.921, GFI = 0.902, and RMSEA = 0.052, indicating a good model fit.

The standardized factor loadings of the observed variables ranged from 0.58 to 0.82, all above the 0.50 threshold and statistically significant ($p < 0.001$). This confirmed that the observed variables adequately explained the latent constructs. Convergent validity was supported, with Average Variance Extracted (AVE) values greater than 0.50 and Composite Reliability (CR) values exceeding 0.70 for each factor. Discriminant validity was also established, as the AVE of each factor was greater than the squared correlations between factors.

Accordingly, the CFA results validated that the five-factor model (aligned with the Ministry of Education and Training's rubric) demonstrated strong reliability and validity, ensuring both internal consistency and practical applicability. This confirms that integrating digital competence

into the courses yielded a coherent and stable assessment structure, suitable for further research as well as for implementation in actual teacher training.

To determine the effectiveness of integrating digital competence into the two courses, inferential statistical methods were applied to test the hypotheses. Based on data collected from 395 students, the paired-samples t-test was used to compare differences in mean digital competence scores between the pretest and posttest stages. In addition, Cohen's d effect size was calculated to measure the magnitude of the intervention's impact. These analyses provided scientific and objective evidence of improvements in students' digital competence, thereby testing the study's hypotheses and confirming the feasibility of integrating digital competence into early childhood teacher education programs.

Table 7. Paired-Samples t -Test Results for Digital Competence Before and After Intervention (N = 395)

Digital Competence (Rubric)	Pretest (M $\pm$ SD)	Posttest (M $\pm$ SD)	t (394)	Sig. (p)	Cohen's d	Interpretation
Digital Literacy & Information	2.91 $\pm$ 0.64	3.78 $\pm$ 0.59	9.42	0.000	0.80	Significant difference, large effect
Digital Communication & Collaboration	2.88 $\pm$ 0.61	3.71 $\pm$ 0.58	8.96	0.000	0.76	Significant difference, medium-to-large effect
Digital Safety & Ethics	2.82 $\pm$ 0.59	3.74 $\pm$ 0.57	9.21	0.000	0.78	Significant difference, large effect
Digital Content Creation	2.89 $\pm$ 0.63	3.85 $\pm$ 0.60	9.54	0.000	0.81	Significant difference, large effect
Artificial Intelligence (AI) Literacy	2.74 $\pm$ 0.61	3.92 $\pm$ 0.58	10.12	0.000	0.85	Significant difference, very large effect

The inferential statistical analysis confirmed that integrating digital competence into the two courses led to significant improvements across all five rubric criteria.

First, Digital Literacy & Information increased from a mean score of 2.91 to 3.78, with a large

effect size ($d = 0.80$). This reflects students' progression from basic information retrieval to the ability to analyze, filter, and apply digital resources to professional assignments. Such advancement was largely driven by learning activities that required students to exploit

multiple online resources and practice standardized citation.

Second, Digital Communication & Collaboration improved substantially ($M = 2.88$ to 3.71 ; $d = 0.76$). Before the intervention, students mainly relied on personal communication tools (e.g., email, Zalo). After structured guidance, they began to employ online platforms for teamwork, discussion, and resource sharing. This shift demonstrates enhanced digital collaboration skills, directly supporting their future practice in early childhood education.

Third, Digital Safety & Ethics rose from 2.82 to 3.74 ($d = 0.78$), showing that students developed stronger awareness of data protection, responsible digital use, and adherence to ethical standards. This competence is critical in early childhood teacher education, as it equips students with habits of safeguarding personal data and respecting children's privacy in digital environments.

Fourth, Digital Content Creation recorded a marked improvement, second only to AI literacy ($M = 2.89$ to 3.85 ; $d = 0.81$). Students progressed from preparing simple lesson plans and slides to designing multimedia learning materials, online games, and video clips that support the care, nurturing, and education of young children. This finding underscores that, when guided and given practice opportunities, students can demonstrate creativity and pedagogical innovation through technology.

Finally, Artificial Intelligence (AI) Literacy showed the most notable improvement ($M = 2.74$ to 3.92 ; $d = 0.85$). Prior to the intervention, students mainly used AI for translation or information searches. After the integration, they learned to exploit AI for generating ideas, designing educational plans, and, crucially, began to evaluate reliability, recognize risks, and consider ethical implications in AI use. This highlights the feasibility and effectiveness of incorporating Section 6 (AI Applications) of the Ministry's Digital Competence Framework into early childhood teacher training programs.

Overall, the results rejected the null hypothesis (H_0) and supported the alternative hypothesis

(H_1): students' digital competence significantly improved after the intervention. With effect sizes ranging from medium to large, the findings affirm that integrating digital competence into teacher education is an effective, practical, and contextually appropriate solution for advancing digital transformation in education.

Discussion

The research findings show that integrating digital competence into specialized early childhood education courses has contributed to a significant improvement in students' digital competence, particularly in their ability to use artificial intelligence (AI) and create digital content. These results align with previous studies emphasizing that comprehensive integration approaches are more effective than standalone ICT training because digital skills are developed within authentic pedagogical contexts (Instefjord & Munthe, 2017; Redecker, 2017). The study also supports the argument that AI-supported learning activities can enhance student engagement, creativity, and problem-solving when accompanied by appropriate pedagogical guidance and reflection on ethics.

From a pedagogical perspective, the proposed integration model suggests that digital competence should not be viewed merely as technical proficiency but as a multidimensional professional competency closely tied to teaching practice. Through activities such as designing AI-supported lessons, collaborative learning, multimedia production, and case-based learning, students gradually shift from passive technology users to active creators and critical evaluators of digital resources. This outcome is consistent with the TPACK perspective, which emphasizes the interaction among technological, pedagogical, and content knowledge in teacher education.

From a psychometric perspective, Cronbach's Alpha coefficients exceeded 0.79 , confirming strong internal reliability of the measurement scale. Both EFA and CFA validated the five-factor structure of the rubric—digital literacy & information, digital communication & collaboration, digital safety & ethics, digital content creation, and AI literacy—ensuring

convergent and discriminant validity. This provides compelling evidence that the constructed assessment tool is appropriate and can be applied in future research. In addition, the hypothesis testing using paired-samples *t*-test revealed statistically significant differences between pretest and posttest scores ($p < 0.01$), with Cohen's *d* effect sizes ranging from 0.76 to 0.85. Notably, AI literacy showed the greatest improvement, reflecting the strong influence of this technology on students' learning and teaching practices.

Alongside the positive outcomes, this study also raises several issues requiring further discussion. First, the application of AI in early childhood education still carries potential risks concerning accuracy, transparency, and ethics; therefore, student training should place greater emphasis on skills related to critical evaluation, selection, and responsible use. Second, the improvement in students' digital competence may be uneven across groups, depending on their prior technological background and self-directed learning abilities—an observation that highlights the need for personalized support in training. Third, the study was limited to only two courses, suggesting the necessity of expanding AI integration to other courses within the curriculum to ensure comprehensive and continuous development of digital competence.

In summary, this study confirms the feasibility and educational value of integrating digital competence into early childhood teacher education curricula through specialized pedagogical courses. The integration model not only enhances students' digital competence and knowledge of artificial intelligence but also promotes the responsible use of technology, pedagogical creativity, and readiness for digital transformation in education. These findings contribute to the growing discourse on digital competence development in teacher education and offer practical implications for curriculum innovation in the context of Education 4.0.

Conclusions And Recommendations

The research findings have confirmed the feasibility and effectiveness of integrating digital

competence into early childhood teacher education curricula. Through an experiment involving 395 students, learners' digital competence showed significant improvement, particularly in two important criteria: the application of artificial intelligence (AI) and digital content creation. Cronbach's Alpha, EFA, and CFA tests demonstrated that the measurement scale employed in this study achieved high reliability and validity, accurately reflecting the five-domain structure of digital competence stipulated in Circular No. 02/2025. Furthermore, the Paired Samples *t*-test results indicated a statistically significant difference between the pre-test and post-test stages ($p < 0.01$), with medium to large effect sizes. This evidence substantiates that the integration of digital competence not only enables students to develop technological skills but also fosters responsible attitudes toward technology use, aligning with professional requirements in the era of educational digital transformation.

To enhance implementation effectiveness, early childhood teacher training institutions should develop a systematic plan for integrating digital competence, ensuring that digital content is embedded across multiple courses rather than being concentrated solely in basic computer science modules. Within this framework, Section 6 – AI Application should be regarded as a core focus, aimed at equipping students with the ability to utilize AI tools responsibly, as well as the capacity to evaluate and critically reflect on AI-generated outputs.

Furthermore, faculty members at pedagogical institutions need to innovate their teaching methods by flexibly combining digital tools to encourage students to practice designing learning materials, applying AI in developing educational plans, and organizing hands-on experiential activities. On the students' part, they should proactively cultivate digital skills, develop habits of lifelong learning in digital environments, and simultaneously enhance their awareness of digital safety and ethics in order to apply these competencies effectively in their future professional practice.

At the macro level, the Ministry of Education and Training should continue to issue detailed guidelines, provide shared digital learning resources, and organize training workshops for faculty at pedagogical institutions. These measures are necessary to ensure consistency and synchronization in implementation, thereby contributing to the improvement of early childhood teacher training quality in the context of Education 4.0.

In conclusion, it can be affirmed that the integration of digital competence into early childhood teacher education curricula—with a focus on artificial intelligence applications—not only enhances training quality but also contributes to shaping a future teaching workforce capable of adaptability, creativity, and guiding children toward safe, humane, and effective engagement with technology.

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