

*International Journal of Learning, Teaching and Educational Research*  
 Vol. 24, No. 7, pp. 753-775, July 2025  
<https://doi.org/10.26803/ijlter.24.7.37>  
 Received May 13, 2025; Revised Jun 25, 2025; Accepted Jul 7, 2025

## AI Literacy Among Future Math Educators: The Mediating Role of Digital Literacy in Mathematics Teaching

Anjie M. Manto\* , Gelyn E. Señedo , Feachy Gay E. Jauculan ,  
 Mary Shein Q. Giangan  and Gerly A. Alcantara   
 Cebu Technological University-Danao Campus  
 Sabang, Danao City, Cebu

**Abstract.** The use of artificial intelligence (AI) in mathematics teaching emphasizes the necessity for future educators to develop digital literacy (DL) and AI literacy (AIL). Despite increasing attention being paid to these competencies, little is known about how DL influences AIL among pre-service mathematics teachers. A descriptive correlational research design was used in this study to assess the levels of DL and AIL, explore their relationship, and profile participants based on gender and year level. Teachers (AILST) instruments, including the Digital Literacy Scale and AI Literacy Scale for Teachers (AILST), measured four AIL dimensions: perception, knowledge and skills, application and innovation, and ethics. Digital literacy was evaluated concurrently. The data were analyzed using IBM SPSS Statistics (version 21). Descriptive statistics (means and standard deviations) summarized overall literacy levels. To determine relationships, Pearson's  $r$  was used to assess the correlation between digital and AI literacy, Spearman's  $\rho$  examined associations with year level, and the chi-square test explored the relationship between gender and literacy variables. Results showed that pre-service teachers had above-average competence of DL and AIL, with a moderate positive correlation between the two, indicating that greater digital fluency supports stronger AI-related competencies. However, notable gaps persist in applying AI for innovation and in critically evaluating AI-generated content. These findings indicate the need to integrate DL and AIL in teacher education programs to prepare aspiring mathematics educators for ethical, effective, and innovative AI use in classrooms, thereby contributing to research-informed instructional practices and responsive curriculum development.

**Keywords:** AI literacy; digital literacy; mathematics teaching; pre-service mathematics teachers

---

\*Corresponding author: Anjie M. Manto, [mantoanjie@gmail.com](mailto:mantoanjie@gmail.com)

## 1. Introduction

Artificial intelligence (AI) integration into mathematics instruction is transforming traditional pedagogical practices. As educational tools evolve, from chalkboards to digital platforms such as Khan Academy, Mathway, and Wolfram Alpha, there is a growing demand for educators to acquire not only teaching expertise but also technological fluency. Digital literacy (DL) is the capacity to utilize, assess, and adapt digital technologies efficiently for purposes such as learning, communication, as well as solving problems (Falloon, 2020). AI literacy (AIL), on the other hand, is the capacity to understand, interact with, and responsibly apply AI technologies in various contexts (Long & Magerko, 2020). These two literacies are interdependent: DL provides the foundational skills necessary to deal with digital environments, while AIL builds on these skills to engage with intelligent systems.

As Chiu et al. (2024) note, DL is a prerequisite for AIL, particularly in education where understanding both the potential and ethical use of AI is critical for effective teaching. Research shows that educators with strong digital abilities are more innovative and efficient in using emerging technologies (Zhao et al., 2021). When combined, these literacies enable teachers to make informed decisions, integrate adaptive AI systems into instruction, and promote learner involvement and individualized instruction (Chiu et al., 2023; Huang et al., 2016).

Though AI-enhanced technologies are increasingly being used in education, there remains a gap between expectations that future teachers are prepared to utilize AI responsibly and the current realities that many pre-service educators lack sufficient preparation in these literacies. While some studies focus on the significance of digital competence, few delve into how DL impacts AIL, particularly within the context of mathematics instruction. This disconnect demonstrates the importance of determining the correlation between DL and AIL in education preparation programs.

The state of existing research highlights the global recognition of digital literacy as a critical skill for integrating AI in education. Lim (2023) found that digital literacy significantly influences pre-service teachers' perceptions of AI, while Mandal and Naskar (2021) noted its impact on using AI tools for personalized instruction in mathematics. However, existing literature has not sufficiently addressed how digital literacy supports the development of AIL, nor how these literacies collectively shape pre-service mathematics teachers' readiness for AI-enhanced teaching. This study responds to that gap by investigating their relationship across four domains: perception, knowledge and skills, application and innovation, and ethics.

This study seeks to evaluate the levels of DL and AIL among aspiring mathematics educators and examine the correlation between these literacies as factors influencing their readiness for instruction. It specifically seeks to determine how digital fluency supports or constrains the development of AIL. The expected outcome is to generate evidence-based insights that can inform the redesign of teacher education curricula, particularly in terms of training in and

exposure to AI tools. These findings will also serve to guide educators, policymakers, and institutions in honing teachers to utilize AI effectively and responsibly in mathematics instruction. Specifically, this research answered the questions that follow:

1. What is the distribution of respondents with respect to:
  - 1.1 Gender and
  - 1.2 Year level?
2. What is the level of digital literacy among pre-service mathematics teachers?
3. What is the level of AI literacy among pre-service mathematics teachers in terms of:
  - 3.1 AI perception.
  - 3.2 AI knowledge and skills.
  - 3.3 AI applications and innovation; and
  - 3.4 AI ethics?
4. Is there a significant relationship between the profile of the respondents (gender and year level) and
  - 4.1 Level of digital literacy; and
  - 4.2 Level of AI literacy?
5. Is there a significant relationship between digital literacy and AI literacy in terms of the following:
  - 5.1 Digital literacy and AI perception.
  - 5.2 Digital literacy and AI knowledge and skills.
  - 5.3 Digital literacy and AI applications and innovation; and
  - 5.4 Digital literacy and AI ethics?

### **1.1 Research Hypotheses**

1. Relationship between DL and respondents' profile
 

*Ho: There is no significant relationship between digital literacy and respondents' profiles in terms of sex and year level.*

*Ha: There is a significant relationship between digital literacy and respondents' profiles in terms of sex and year level.*
2. Relationship between AIL and respondents' profile
 

*Ho: There is no significant relationship between AI literacy and respondents' profiles in terms of sex and year level.*

*Ha: There is a significant relationship between AI literacy and respondents' profiles in terms of sex and year level.*
3. Relationship between DL and AIL
  - 3.1 *Ho: There is no significant relationship between digital literacy and AI perception.*
  - Ha: There is a significant relationship between digital literacy and AI perception.*

3.2 *Ho: There is no significant relationship between digital literacy and AI knowledge and skills.*

*Ha: There is a significant relationship between digital literacy and AI knowledge and skills.*

3.3 *Ho: There is no significant relationship between digital literacy and AI applications and innovation.*

*Ha: There is a significant relationship between digital literacy and AI applications and innovation.*

3.4 *Ho: There is no significant relationship between digital literacy and AI ethics.*

*Ha: There is a significant relationship between digital literacy and AI ethics.*

## **2. Literature Review**

### **2.1 Pre-service Teacher's Artificial Intelligence Literacy (TAIL) Definition**

AI literacy (AIL), a vital competency for teachers, involves understanding AI concepts, applying AI-related skills, using AI effectively in education, and recognizing its ethical implications (Ayanwale et al., 2024). For pre-service teachers, strong AIL is essential for integrating AI into future classrooms. AIL is typically viewed from two perspectives: foundational and specialized literacy. Foundational literacy covers basic AI knowledge and critical engagement with AI as an academic aid (Ning et al., 2025). Kong et al. (2021) identified three foundational elements: understanding AI principles, using AI for assessment, and solving real-world problems.

Specialized literacy, on the other hand, focuses on using AI in instruction. It involves mastering AI tools and strategies to develop teaching-learning processes, support diverse learners, and promote critical thinking (Ning et al., 2025; Zhao et al., 2022). Overall, AIL comprises more than technical proficiency; it includes ethical awareness and critical thinking. By developing AIL, pre-service teachers can build inclusive, innovative, and future-ready classrooms, equipping learners to adapt to an AI-enhanced environment.

### **2.2 TAIL Paradigm**

As AI continues to influence education, developing future teachers' capabilities to integrate AI tools with integrity and proficiency has become crucial. The Teachers AI Literacy (TAIL) Framework offers a comprehensive model for developing AI literacy, equipping future educators with both technical knowledge and ethical, pedagogical insights.

A review of the literature reveals several globally recognized TAIL frameworks for AI literacy. Broad frameworks, such as those proposed by Long and Magerko (2020) and Touretzky (2019), outline key competencies. Long and Magerko (2020) focus on 17 competencies divided into five central queries: what AI is and how it works, as well as its uses. Touretzky's (2019) Five Big Ideas emphasize hands-on experiences with AI to enhance practical understanding and skills.

Three-dimensional and four-dimensional models are the main classifications into which TAIL frameworks fall, with the former being widely adopted in

research. For example, Kong and Zhang (2021) define AIL through cognitive, affective, and sociocultural dimensions, focusing on AI knowledge, collaboration using AI, and ethical implications. Similarly, Kim et al. (2021) emphasize the need for AI understanding, skills, and mindsets to critically apply AI's societal impact. Kong et al. (2021) propose understanding AI basics, applying these concepts, and solving real-world problems using AI. Other scholars have contributed models that expand the scope of AI literacy. Sattelmaier and Pawlowski (2023) categorized competencies into basic, AI, and emerging competencies. Lorenz and Romeike (2023) introduced the AI-PACK model consisting of three areas that parallel Shulman's pedagogical knowledge framework.

In response to AI's expanding role in education, some frameworks have evolved to include four or more dimensions. Wang et al. (2023) introduced the dimensions: knowledge, application, assessment, and ethics. Ng et al. (2021) structured a cognitive-level framework based on Bloom's taxonomy, consisting of knowing, using, creating, and evaluating AI, while addressing ethical considerations. Carolus (2023) added dimensions such as AI self-efficacy, which emphasizes problem-solving abilities and a mindset of continuous learning, and AI self-competency, recognizing AI's emotional influence. Ayanwale (2024) extended this structure into an eight-dimensional model, incorporating AI persuasion literacy, emotion regulation, and problem-solving. These extensions indicate the increasing difficulty of AI literacy and the importance of using diverse strategies in preparing teachers.

Additionally, some frameworks, such as UNESCO's AI Competency Framework for Teachers, organize AI literacy along two axes: horizontal and vertical. The former aligns with Bloom's cognitive theory, covering stages from understanding to creation. The latter includes essential components comprising professional education in AI, core knowledge, student-oriented practices, and the application of AI tools and instructional strategies (Chiu et al., 2024). Pinski and Benlian (2023) proposed a five-dimensional model focusing on familiarity with AI technologies, human-AI interaction, understanding AI processes, hands-on AI experience, and practical experience in AI system development.

The most recent development is the TAIL model introduced by Ning et al. (2025), consisting of perception, knowledge and skills, applications and innovation, and ethics. AI perception includes perceived usefulness and ease of use, while the second includes teachers' understanding of fundamental AI concepts and their ability to apply these in educational contexts. The third assesses the extent to which pre-service teachers can use AI tools creatively and effectively in the classroom. The last dimension is treated as a distinct dimension. The AI Literacy Scale for Teachers (AILST) developed alongside this model was validated through empirical studies.

In conclusion, these advancements have driven the development of various AI literacy frameworks. Whether three-dimensional, four-dimensional, or beyond, these frameworks show the importance of a comprehensive strategy that

combines technical knowledge with ethical and pedagogical principles. Equipping future teachers with a well-rounded comprehension of AI through these validated frameworks will prepare them to utilize AI responsibly and ethically.

### 2.2.1 AI Perception (AIP)

Teachers' desire to utilize AI in teaching is greatly influenced by how they view technology (Teo et al., 2019; Yuan et al., 2023). If they believe AI is useful for enhancing teaching and learning, its adoption is more likely. However, if they perceive it as ineffective, its potential remains unutilized (Ning et al., 2022).

The Technology Acceptance Model (TAM) (Davis, 1989) helps explain this relationship by focusing on two key components: perceived usefulness and perceived ease of use. The former concerns the idea that AI improves task performance, such as supporting teachers in their instructional duties (Zhang et al., 2023). On the other hand, the latter pertains to the perceived convenience with which educators believe they may effectively utilize AI (Abdullah et al., 2016). If aspiring teachers view AI as valuable and simple to use, they are more inclined to apply it to the teaching-learning process which will improve student performance and encourage creativity.

### 2.2.2 AI Knowledge and Skills (AIKS)

Future educators must acquire AIKS to adapt to the evolving educational setting. A strong understanding of AI enables them to support student development and participate in meaningful conversations about the use of AI in teaching (Kim & Kwon, 2023; Ning et al., 2024). AI knowledge lays the foundation for incorporating AI into teaching, while AI skills are the technical proficiency needed to utilize resources such as ChatGPT, Mathway, and Microsoft Math Solver (Benvenuti, 2023).

Teachers proficient in AI tools are more likely to embrace digital transformation, thereby improving instructional and administrative tasks (Huang, 2021). As Markauskaite (2022) emphasized, integrating digital technologies is vital for meeting educational standards and engaging in ongoing professional development. Hands-on experience with AI tools ensures educators remain receptive to the demands of 21st-century students. Therefore, assessing AI knowledge and skills is crucial for evaluating their readiness to incorporate AI in the teaching-learning process.

### 2.2.3 AI Applications and Innovation (AI AI)

AI has transformed teaching methods and enhanced learning experiences. AI applications involve using AI tools to improve lesson planning, instruction, and student evaluation (Carolus et al., 2023). This builds on teachers' AI expertise and abilities, allowing them to incorporate these resources effectively into the instruction.

AI innovation emphasizes the creative use of AI in classrooms, where educators integrate it into teaching strategies to promote student growth (Guan et al.,

2020). Teachers must not only understand AI but also apply it to enhance teaching effectiveness.

To do so, educators should design AI-driven activities that align with real-world classroom needs, such as personalizing instruction and differentiating learning tasks. Tools such as TutorAI and Perplexity can provide customized learning materials for more targeted instruction (Poquet & De Laat, 2021). Effective AI integration requires educators to embrace both functional and innovative aspects, creating dynamic, inclusive, and responsive learning environments.

#### 2.2.4 AI Ethics (AIE)

AIE in education is crucial as AI becomes increasingly incorporated into teaching. Educators are responsible for promoting the ethical, equitable, and transparent use of AI, ensuring student data is protected and no harm is caused (Bleher & Braun, 2023). Risks including bias, unfairness, and data vulnerabilities which could emerge in the absence of defined ethical rules (Kousa & Niemi, 2023). Educators must make informed choices on what, when, and how to use AI to ensure fair outcomes, guided by clear policies (Adams et al., 2023). They are obligated to select AI systems that prioritize fairness and prevent security threats (Bond et al., 2024). Ethical AI integration is a necessity, not a choice. For pre-service educators, understanding AI ethics is critical, as it will shape how they apply emerging technologies in classrooms and uphold professional standards throughout their careers.

### 2.3 DL and AIL in Mathematics Education

DL in mathematics teaching includes the strategic utilization of digital materials in utilizing, analyzing, creating, and communicating mathematical information (Geraniou & Jankvist, 2019). It includes technical skills, cognitive abilities such as problem-solving with digital tools, and socio-emotional competencies such as collaboration in digital environments (Ng, 2012). Tools such as GeoGebra, Desmos, and digital assessment platforms enhance math learning through visualization and interactivity (Viberg et al., 2023). For aspiring educators, DL is essential for delivering engaging instruction, supporting diverse learners, and navigating online and hybrid teaching environments (Cirneanu & Moldoveanu, 2024; Haleem et al., 2022). Digitally literate teachers also model technological competence for students (Voogt et al., 2015).

Moreover, AIL builds on digital literacy by equipping educators to interpret, assess, and ethically implement AI academically (Ng et al., 2021). In mathematics, this includes intelligent tutoring systems, AI-powered feedback, and data-driven personalization (Chen et al., 2020). AI-literate teachers can automate grading, pinpoint areas of improvement, and differentiate instruction to individual needs (Pane et al., 2017), while also promoting learners' critical thinking and ethical awareness (Jarke & Breiter, 2019; Zawacki-Richter et al., 2019).

As Chiu et al. (2024) emphasize, DL serves as a foundation for building AIL. Research shows that teachers with strong digital skills are more innovative and effective (Zhao et al., 2021). Both literacies positively impact student

achievement when thoughtfully integrated (Hasibuan et al., 2024; VanLehn, 2011).

Despite these benefits, challenges persist limited access to tools, lack of training, and ethical challenges hinder effective implementation (Ertmer & Ottenbreit-Leftwich, 2010; Howard et al., 2021). Addressing these requires targeted teacher preparation, ongoing support, and equitable access (Baker et al., 2016; Tondeur et al., 2017). Hence, equipping future mathematics educators with both digital and AI literacy is vital for creating responsive, inclusive, and future-ready learning environments.

### **3. Methods**

This study examines DL and AIL levels among pre-service mathematics teachers using quantitative research. Descriptive statistics assesses literacy levels, while inferential statistics examines the correlations between digital and AI literacy. Data was collected through Google Forms for math teacher education students in Central Visayas.

#### **3.1 Research Design**

A descriptive correlational research design was used in determining the correlation between DL and AIL among pre-service mathematics teachers. This design was chosen because it allows for the natural observation of variables without manipulation, upholding the integrity of the educational setting and enabling the identification of context-specific insights relevant to teacher education. Respondents were profiled based on demographics such as gender and year level for a more focused analysis.

Their digital and AI literacy levels were assessed as well. The study also investigated correlations between DL and the four dimensions of AIL: perception, knowledge and skills, applications and innovation, and ethics, providing a multidimensional analysis as reflected in the results (Sections 4.3.1 to 4.3.4). By examining naturally occurring variables, this approach supports the development of evidence-based pedagogical strategies and curriculum improvements for technology-integrated instruction in mathematics education.

#### **3.2 Research Instrument**

To ensure data validity and reliability, this study adopted standardized survey items from previously validated instruments. The Digital Literacy Scale (Avinç & Doğan, 2024) consists of 20 items assessing digital content competencies, rated on a five-point Likert scale (Strongly disagree to Strongly agree). The AI Literacy Scale for Teachers (Ning et al., 2025), selected for its comprehensive coverage of AI literacy dimensions relevant to teacher education, contains 36 items across four dimensions: AIP (10 items), AIKS (10 items), AIAI (8 items), and AIE (8 items), rated on a five-point applicability scale (Fully not applicable to Fully applicable). The choice of these instruments was based on their demonstrated validity in prior studies and their alignment with the competencies required for aspiring mathematics educators.

This study did not conduct an independent validation or pilot testing of the instruments. The validity and reliability of the instruments were assumed based on their prior use in the originally published research. The final instrument included four parts: informed consent, demographic information, digital literacy, and AI literacy, with subsections for each AI dimension.

### **3.3 Research Sample and Respondents**

The study surveyed 117 aspiring mathematics educators enrolled in the Bachelor of Secondary Education major in Mathematics across Central Visayas. Purposive sampling was used to ensure that participants had exposure to technology-integrated instruction and AI use in academic contexts. This approach was chosen to target individuals most likely to provide meaningful insights into digital and AI literacy within teacher education. Respondents (n=117) were determined based on the total number of eligible learners available during the data collection period, ensuring representation from all academic year levels and maximizing the diversity of experiences captured. Demographic information (gender and year level) was collected to profile participants. Participation was voluntary, with informed consent obtained and ethical considerations strictly observed.

### **3.4 Data Collection Procedure**

Google Forms served as the tool for data gathering which facilitated the transformation of the validated survey questionnaire into an accessible online format. The survey was made accessible to all qualified participants through both institutional outlets and social media platforms. Duplicate responses were not allowed, and participants were reminded of the study's objectives, their voluntary participation, and their right to discontinue at any stage. Informed consent was provided digitally before respondents proceeded to the survey. Confidentiality and data security were maintained throughout the process, with all responses stored securely for analysis.

### **3.5 Data Analysis**

Data analysis was conducted using IBM SPSS Statistics version 21. Descriptive statistics (means, standard deviations) summarized digital and AI literacy scores, providing an overview of participants' competencies. Inferential statistics was used to investigate the correlation between variables: Pearson's  $r$  correlation assessed the relationship between digital and AI literacy, Spearman's  $\rho$  explored associations with year level, and the chi-square test analysed the relationship between gender and literacy scores. These methods were chosen for their appropriateness in analysing the types of data collected and their ability to provide clear insights into both descriptive characteristics and key relationships within the sample.

## **4. Results**

This section covers respondents' demographics, digital and AI literacy levels, relationships between profiles and literacy levels, and correlation between AIL and DL levels among pre-service math educators.

#### 4.1 Respondents' Demography

Table 1 answers RQ1 by describing the distribution of respondents by gender and year level. It presents the demographics of 117 BSEd Mathematics pre-service teachers from Central Visayas. Most respondents were female (99), with fewer males (18). In terms of year level, the majority were 4th-year students (43), followed by 1st-year (33), 2nd-year (25), and 3rd-year (16) students.

**Table 1: Respondents' Demography**

Gender ( $n=117$ )	Male	18
	Female	99
Year level ( $n=117$ )	1st year	33
	2nd year	25
	3rd year	16
	4th year	43

#### 4.2 DL among Pre-Service Math Teachers

Table 2 shows the DL levels of pre-service mathematics teachers on 20 statements. The total mean score is 4.03 with a standard deviation of 0.74, indicating agreement with the statements and low response variation. Several items, such as DL1 ( $M = 4.52$ ), DL2 ( $M = 4.56$ ), and DL4 ( $M = 4.61$ ), received "Strongly agree," reflecting high levels of confidence in digital skills. Most items fell under "Agree," showing positive self-assessment. One item, DL7 ( $M = 3.43$ ), received a "Neutral" response, indicating uncertainty in that area. Standard deviations ranged from 0.52 to 0.88, suggesting consistent responses with minimal variation.

**Table 2: Level of DL among pre-service math teachers**

Statement	Mean	SD	Verbal Description	Interpretation by Standard Deviation
DL1	4.52	0.52	Strongly agree	Low dispersion
DL2	4.56	0.77	Strongly agree	Low dispersion
DL3	4.37	0.65	Agree	Low dispersion
DL4	4.61	0.59	Strongly agree	Low dispersion
DL5	4.20	0.73	Agree	Low dispersion
DL6	3.92	0.82	Agree	Low dispersion
DL7	3.43	0.71	Neutral	Low dispersion
DL8	3.80	0.71	Agree	Low dispersion
DL9	4.09	0.75	Agree	Low dispersion
DL10	3.88	0.76	Agree	Low dispersion
DL11	3.91	0.78	Agree	Low dispersion
DL12	3.87	0.75	Agree	Low dispersion
DL13	3.70	0.73	Agree	Low dispersion
DL14	3.97	0.86	Agree	Low dispersion
DL15	3.62	0.88	Agree	Low dispersion
DL16	4.33	0.77	Agree	Low dispersion
DL17	4.46	0.64	Agree	Low dispersion
DL18	4.24	0.76	Agree	Low dispersion

DL19	3.61	0.85	Agree	Low dispersion
DL20	3.57	0.84	Agree	Low dispersion
<b>Average</b>	<b>4.03</b>	<b>0.74</b>	<b>Agree</b>	<b>Low dispersion</b>

### 4.3 AIL level among Pre-Service Math Teachers

#### 4.3.1 Level of AI Perception Among Pre-Service Math Teachers

Table 3 shows the perception of AI among future mathematics educators based on ten statements. The total mean score is 4.02, with a standard deviation of 0.69, indicating agreement with AI's applicability. Items AIP1 ( $M = 4.30$ ), AIP2 ( $M = 4.18$ ), and AIP3 ( $M = 4.11$ ) received higher scores, suggesting stronger agreement. Items AIP8 ( $M = 3.79$ ) and AIP10 ( $M = 3.91$ ) had slightly lower scores but still indicated AI's relevance. The standard deviations, ranging from 0.57 to 0.79, reflect low dispersion, showing general consensus among participants on AI's applicability in their future teaching roles.

**Table 3: Level of AI perception among pre-service math teachers**

Statements	Mean	SD	Verbal Description	Interpretation by Standard Deviation
AIP1	4.30	0.71	Applicable	Low dispersion
AIP2	4.18	0.57	Applicable	Low dispersion
AIP3	4.11	0.61	Applicable	Low dispersion
AIP4	4.03	0.70	Applicable	Low dispersion
AIP5	4.15	0.70	Applicable	Low dispersion
AIP6	3.87	0.70	Applicable	Low dispersion
AIP7	3.85	0.75	Applicable	Low dispersion
AIP8	3.79	0.69	Applicable	Low dispersion
AIP9	4.05	0.69	Applicable	Low dispersion
AIP10	3.91	0.79	Applicable	Low dispersion
<b>Average</b>	<b>4.02</b>	<b>0.69</b>	<b>Applicable</b>	<b>Low dispersion</b>

#### 4.3.2 Level of AI Knowledge and Skills among Pre-service Math Teachers

Table 4 presents the level of AI knowledge and skills among aspiring mathematics educators on ten statements. The overall mean score is 4.00, with a standard deviation of 0.71, suggesting widespread approval of AI's applicability. Items AIKS3 ( $M = 4.03$ ), AIKS4 ( $M = 4.13$ ), and others receive higher scores, showing confidence in AI skills. Items AIKS1 ( $M = 3.75$ ) and others have lower scores, indicating uncertainty in some areas. Standard deviations ranging from 0.60 to 0.86 reflect consistent responses. While responses were generally consistent, the data shows higher levels of confidence in practical AI applications such as AIKS4 and AIKS8, and lower confidence in technical aspects such as AIKS1, indicating both strengths and areas for improvement in AIKS.

In response to RQ3.2, the results demonstrate that aspiring educators show strong AI literacy across all four domains, with the highest confidence observed in AI perception. This suggests a positive disposition and familiarity with AI concepts relevant to their future teaching profession.

**Table 4: Level of AI knowledge and skills among pre-service math teachers**

Statements	Mean	SD	Verbal Description	Interpretation by Standard Deviation
AIKS1	3.75	0.86	Neutral	Low dispersion
AIKS2	3.89	0.61	Neutral	Low dispersion
AIKS3	4.03	0.60	Applicable	Low dispersion
AIKS4	4.13	0.62	Applicable	Low dispersion
AIKS5	3.91	0.77	Neutral	Low dispersion
AIKS6	4.11	0.68	Applicable	Low dispersion
AIKS7	4.00	0.66	Applicable	Low dispersion
AIKS8	4.20	0.84	Applicable	Low dispersion
AIKS9	4.12	0.73	Applicable	Low dispersion
AIKS10	3.86	0.75	Neutral	Low dispersion
<b>Average</b>	<b>4.00</b>	<b>0.71</b>	<b>Applicable</b>	<b>Low dispersion</b>

#### 4.3.3 AI Applications and Innovation among Pre-Service Math Teachers

Table 5 shows the aspiring mathematics educators' responses regarding AI applications and innovation. The total mean score is 3.83, with a standard deviation of 0.74, indicating "Neutral" perception and consistent responses. Items AIAI4 (M = 4.08), AIAI5 (M = 4.05), and others were rated "Applicable," showing acknowledgment of AI's relevance. AIAI2 (M = 3.63) and AIAI3 (M = 3.80) receive "Neutral" ratings, indicating uncertainty. AIAI1 (M = 2.76) has the highest standard deviation (1.06), suggesting varied perceptions. Most other items have low standard deviations (0.65–0.75), indicating relatively consistent responses across participants.

However, the presence of neutral ratings in AIAI2 and AIAI3, despite this consistency, suggests that pre-service teachers may share similar views that reflect limited knowledge or confidence. This highlights the need for further exposure and training, especially in applying AI tools effectively in educational contexts.

In response to RQ3.3, this domain reveals that although aspiring teachers acknowledge the importance of AI in teaching, their application-oriented skills and confidence are still developing. The neutral perception suggests that AI integration in real-world teaching remains an area that requires support and further curriculum enhancement.

**Table 5: AI applications and innovation among pre-service math teachers**

Statements	Mean	SD	Verbal Description	Interpretation by Standard Deviation
AIAI1	2.76	1.06	Uncertain	High dispersion
AIAI2	3.63	0.69	Neutral	Low dispersion
AIAI3	3.80	0.75	Neutral	Low dispersion
AIAI4	4.08	0.65	Applicable	Low dispersion
AIAI5	4.05	0.67	Applicable	Low dispersion
AIAI6	4.16	0.69	Applicable	Low dispersion
AIAI7	4.03	0.71	Applicable	Low dispersion
AIAI8	4.12	0.69	Applicable	Low dispersion
<b>Average</b>	<b>3.83</b>	<b>0.74</b>	<b>Neutral</b>	<b>Low dispersion</b>

#### 4.3.4 AI Ethics among Pre-Service Math Teachers

Table 6 shows pre-service mathematics teachers' responses regarding AI ethics understanding. The total mean score is 4.08, with a standard deviation of 0.77, indicating consistent responses. Items AIE7 (M = 4.51) and AIE8 (M = 4.55) received the highest scores, showing strong recognition of AI ethics' relevance. Other items, such as AIE1 (M = 4.36) and AIE3 (M = 4.13), also reflected positive perceptions. AIE2 (M = 2.55) received an "Uncertain" rating with a high standard deviation (1.29), suggesting varied perceptions. Most items have low dispersion on standard deviations (0.58–0.79), indicating general agreement on the significance of AI ethics in future instructional practices.

This addresses RQ2 by confirming that pre-service mathematics teachers demonstrate an overall high level of DL. This reflects their readiness to use digital tools in academic and professional settings.

**Table 6: Level of AI Ethics among pre-service math teachers**

Statement	Mean	SD	Verbal Description	Interpretation by Standard Deviation
AIE1	4.36	0.69	Applicable	Low dispersion
AIE2	2.55	1.29	Uncertain	High dispersion
AIE3	4.13	0.79	Applicable	Low dispersion
AIE4	4.09	0.78	Applicable	Low dispersion
AIE5	4.20	0.71	Applicable	Low dispersion
AIE6	4.27	0.69	Applicable	Low dispersion
AIE7	4.51	0.64	Applicable	Low dispersion
AIE8	4.55	0.58	Applicable	Low dispersion
<b>Average</b>	<b>4.08</b>	<b>0.77</b>	<b>Applicable</b>	<b>Low dispersion</b>

#### 4.4 Relationship Between DL and Respondents' Profile

Table 7 presents the response to RQ4.1 indicating the statistical results examining the correlation between gender and DL using the chi-square test, and between year level and DL using Spearman's rho. The chi-square test yields a value of 38.563 with a p-value of 0.23. The p-value, greater than the significance level of 0.05, means that the null hypothesis is accepted, indicating no statistically significant association between gender and DL. Similarly, the

Spearman's rho correlation between year level and DL is -0.101 with a p-value of 0.278. This also exceeds the 0.05 level of significance, suggesting no significant relationship between a student's year level and their digital literacy. These findings imply that DL levels are relatively uniform across different genders and academic levels. In other words, male and female respondents, whether in lower or higher year levels, demonstrate comparable levels of DL. This uniformity suggests that DL among aspiring math educators in the sample does not vary based on these demographic factors.

**Table 7: Significant relationship between DL and the respondents' profile**

Digital Literacy Level		p-value	Decision Rule	Remarks
Between genders	$\chi^2 = 38.563$	0.23	Accept Ho	Not significant
Between year levels	$p = -.101$	0.278	Accept Ho	Not significant

#### 4.5 Relationship Between AIL and Respondents' Profile

Table 8 shows the chi-square value (50.168) and p-value (0.387) for the relationship between gender and AIL among future math educators. The null hypothesis is accepted because there is no significant association, as indicated by the p-value falling above 0.05. Similarly, Spearman's rho for year level and AIL is -0.172 with a p-value of 0.063, also above 0.05, showing no significant relationship.

These results suggest that both gender and year level do not significantly influence AIL. Male and female pre-service teachers, regardless of academic year, share similar levels of AIL, indicating consistency in AIL across demographic groups within the sample. This implies a relatively uniform development of these competencies across demographic groups in the sample.

**Table 8: Relationship between AIL and the respondents' profile**

Level of Digital Literacy		p-value	Decision Rule	Remarks
Between genders	$\chi^2 = 50.168$	0.387	Accept Ho	Not significant
Between year levels	$p = -.172$	0.063	Accept Ho	Not significant

#### 4.6 Relationship Between DL and AIL among Pre-service Math Teachers

In response to RQ5, Table 9 shows the correlation between DL and four dimensions of AIL. All relationships were statistically significant ( $p = 0.00$ ), indicating strong associations. Digital Literacy and AI Perception as well as AI Ethics ( $r = 0.55$ ) have a moderate positive correlation ( $r = 0.68$ ), while the same applies to AI Knowledge and Skills ( $r = 0.61$ ). However, DL moderately correlates with AI Applications and Innovation ( $r = 0.56$ ). Since all p-values were below 0.05, the null hypothesis was rejected, confirming significant

relationships. These findings suggest that as pre-service math teachers' DL increases, their competence in all aspects of AIL also improves. This emphasizes the foundational role of digital skills in enhancing AI understanding and capability, implying that strengthening digital literacy is a critical step toward developing well-rounded AI-literate educators in the mathematics field.

**Table 9: Significant relationship between DL and AIL among pre-service math teachers**

<b>Digital Literacy and AI Literacy among Pre-Service Math Teachers</b>	<b>r</b>	<b>p-value</b>	<b>Decision Rule</b>	<b>Remarks</b>
DL and AI perception	0.68	0.00	Reject Ho	Significant
DL and AI knowledge and skills	0.61	0.00	Reject Ho	Significant
DL and application and innovation	0.56	0.00	Reject Ho	Significant
DL and AI ethics	0.55	0.00	Reject Ho	Significant

## 5. Discussion

The study investigates the DL and AIL levels of future mathematics educators in Central Visayas and explores how these literacies interrelate within mathematics education. The results revealed that participants generally demonstrated above-average DL, with most expressing strong confidence in foundational competencies such as basic operations, information literacy, and the use of educational digital tools. This consistency across year levels and gender suggests widespread use of digital literacy in education and successful integration of these skills into teacher education programs. The findings support prior studies demonstrating that aspiring teachers exhibit confidence in using educational tools and accessing information (Hatlevik et al., 2015; Tondeur et al., 2017).

Examining the profile of respondents, the sample included pre-service mathematics teachers distributed across gender and year levels, with no significant differences in DL or AIL observed between these groups. This indicates that individual experiences and access to resources may influence literacy levels more than demographic factors such as gender or academic standing, a pattern supported by earlier studies (Jan 2018; Monteiro & Leite, 2021; Park & Nam, 2014; Rafi et al., 2019; Yang, 2025).

Regarding digital literacy, participants demonstrated strong competency in foundational skills in the utilization of educational digital technologies. The uniformity of these skills across gender and year level further supports the effective incorporation of digital literacy in teacher education. However, confidence declines when it comes to higher-order digital skills, particularly in critically evaluating technological applications. This gap points to the need for targeted interventions aimed at developing advanced digital competencies among pre-service teachers, consistent with findings by Spante et al. (2018).

In terms of AI literacy, aspiring mathematics educators show positive perceptions and confidence in basic AI tools such as ChatGPT and AI-based calculators, recognizing AI's potential for personalized learning and pedagogical innovation (Kaswan et al., 2024; Sing et al., 2022). Nevertheless, confidence is notably lower in the areas of AI applications and innovation, suggesting limited hands-on experience and practical engagement with AI technologies.

This shortfall may be attributed to institutional constraints and insufficient curricular integration of AI, which restrict opportunities for experiential learning and innovation in teaching practices (Lucas et al., 2025; Zawacki et al., 2019). Awareness of AI ethics was generally high, especially regarding fairness and transparency, but uncertainty remained around data privacy and academic integrity, reflecting broader concerns in AI ethics (Ayanwale et al., 2024).

The study also found no significant relationships between respondents' gender or year level and their digital or AI literacy levels, reinforcing the idea that demographic variables may be less influential than access to resources and individual experiences in shaping these literacies. Importantly, the statistical analysis revealed a significant positive correlation between DL and AIL across all dimensions – perception, knowledge and skills, applications and innovation, and ethics.

This finding highlights the foundational role of digital literacy in enabling effective and ethical AI use among future mathematics teachers (Ilomäki et al., 2016; Ng et al., 2023). Without a solid DL base, teachers may struggle to engage with AI beyond superficial levels, limiting their ability to innovate and integrate AI meaningfully into their teaching (Hur, 2025).

From a pedagogical perspective, these findings suggest that embedding AI literacy into mathematics instruction should extend beyond curriculum content to include practical, hands-on experiences and ethical considerations. Teacher preparation programs should ensure the provision of hands-on experiences using AI tools in real-world teaching contexts to promote creativity, critical thinking, and ethical application. Institutional support is also crucial; issues involving limited technological availability and a limited emphasis on the current curriculum must be addressed to close the gap in AI application and innovation skills.

Practically, educators can use the strong foundational digital skills of pre-service teachers as a springboard for integrating AI into mathematics teaching. Professional development programs should focus on enhancing advanced digital competencies and providing frameworks for ethical AI use, equipping teachers to handle the challenges of AI integration in education with ethical awareness.

Comparing these findings with national and international literature confirms consistent patterns in DL and AIL among aspiring teachers, reinforcing the global relevance of integrating these literacies in teacher preparation (Hatlevik et

al., 2015; Kaswan et al., 2024; Sing et al., 2022; Tondeur et al., 2017). This study offers valuable insights to the academic community by highlighting the interplay between digital and AI literacies, thus, emphasizing the need for comprehensive, multidimensional approaches to literacy development in mathematics education.

In conclusion, integrating digital and AI literacies is crucial for honing future mathematics educators to teach with creativity, responsibility, and confidence. Strengthening digital competence enhances AI literacy, enabling teachers to harness AI's educational potential fully and ethically.

## 6. Conclusion and Recommendations

This study emphasizes the need to strengthen both DL and AIL among future mathematics teachers to equip them for AI-integrated classrooms. While participants demonstrate strong digital literacy and above-average AI literacy, particularly in perception, knowledge, skills, and ethics, a clear gap was observed in AI application and innovation. A moderate positive correlation between digital and AI literacy suggests that digital competence supports the development of AI capabilities. However, no significant correlation was found between literacy levels and demographic variables, indicating that training, exposure, and engagement are more critical than background characteristics.

Given these findings, teacher education programs should embed structured AI literacy into the curriculum, combining technical training with ethical awareness, particularly on data privacy, fairness, and responsible use. Practical, skill-building experiences, such as engagement with AI-powered tools such as Mathway, Khan Academy, and Wolfram Alpha, can help bridge theory and practice.

Strengthening digital literacy remains foundational, as it supports the effective use of AI in lesson planning, instruction, and assessment. Programs must prioritize experiential learning to boost confidence in AI integration, introduce these competencies early, and ensure equitable access to technologies. Continuous professional learning is essential, alongside the adoption of performance-based assessments to evaluate AI literacy growth and ensure meaningful learning outcomes.

## 7. Limitations and Future Studies

Despite offering valuable insights, this study is limited to 117 pre-service mathematics educators in Central Visayas. This narrows the scope of generalization of its findings to other disciplines, regions, and academic contexts. The use of self-reported data and the inclusion of only two demographic variables, gender and year level, further limit the depth of comparative analysis and raise concerns about overgeneralization.

Future research should involve broader and more diverse samples across fields and locations, and incorporate additional variables such as type of institution, socioeconomic status, parental scaffolding, and access to technology. They may

also incorporate interviews or open-ended responses to enrich the findings and explore these aspects more deeply. Mixed methods or longitudinal approaches are also recommended to explore how digital and AI literacy evolve from initial training through early teaching practice. Examining institutional factors such as school culture, mentorship, and resource availability can deepen understanding and support targeted interventions in teacher education.

Based on these limitations, teacher preparation programs should embed structured AI literacy within the curriculum, emphasizing not only technical skills but also ethical competencies through case-based discussions on data privacy, fairness, and responsible AI use. Practical exposure to AI-powered tools such as Mathway, Khan Academy, and Wolfram Alpha can bridge theoretical knowledge with classroom application. Strengthening digital literacy remains crucial, as it underpins effective AI integration in instruction and assessment.

Institutions should support experiential learning opportunities, ensure equal access to technology, and promote ongoing professional improvement for educators. To ensure meaningful learning outcomes, performance-based assessments must be adopted to track AI literacy growth. Collectively, these strategies are vital to preparing competent, confident, and ethically grounded educators for AI-integrated teaching environments.

## 8. References

- Abdullah, F., Ward, R., & Ahmed, E. (2016). Investigating the influence of the most commonly used external variables of TAM on students' Perceived Ease of Use (PEOU) and Perceived Usefulness (PU) of e-portfolios. *Computers in Human Behavior*, *63*, 75–90. <https://doi.org/10.1016/j.chb.2016.05.014>
- Adams, C., Pente, P., Lermeyer, G., & Rockwell, G. (2023). Ethical principles for artificial intelligence in K-12 education. *Computers and Education: Artificial Intelligence*, *4*, 100131. <https://doi.org/10.1016/j.caeai.2023.100131>
- Avinç, E., & Doğan, F. (2024). Digital literacy scale: Validity and reliability study with the Rasch model. *Education and Information Technologies*, *29*, 22895–22941. <https://doi.org/10.1007/s10639-024-12662-7>
- Ayanwale, M. A., Adelana, O. P., Molefi, R. R., Adeeko, O., & Ishola, A. M. (2024). Examining artificial intelligence literacy among pre-service teachers for future classrooms. *Computers and Education Open*, *6*, 100179. <https://doi.org/10.1016/j.caeo.2024.100179>
- Ayanwale, M. A., Frimpong, E. K., Opesemowo, O. A. G., & Sanusi, I. T. (2024). Exploring factors that support pre-service teachers' engagement in learning artificial intelligence. *Journal for STEM Education Research*, *8*, 199–229. <https://doi.org/10.1007/s41979-024-00121-4>
- Baker, R. S., Martin, T., & Rossi, L. M. (2016). Educational data mining and learning analytics. In A. A. Rupp & J. P. Leighton (Eds.), *The Wiley handbook of cognition and assessment: Frameworks, methodologies, and applications* (pp. 379–396). Wiley. <https://doi.org/10.1002/9781118956588.ch16>
- Benvenuti, M., Cangelosi, A., Weinberger, A., Mazzoni, E., Benassi, M., Barbaresi, M., & Orsoni, M. (2023). Artificial intelligence and human behavioral development: A perspective on new skills and competences acquisition for the educational context. *Computers in Human Behavior*, *148*, 107903. <https://doi.org/10.1016/j.chb.2023.107903>

- Bleher, H., & Braun, M. (2023). Reflections on putting AI ethics into practice: How three AI ethics approaches conceptualize theory and practice. *Science and Engineering Ethics*, 29(3), 21. <https://doi.org/10.1007/s11948-023-00443-3>
- Bond, M., Khosravi, H., De Laat, M., Bergdahl, N., Negrea, V., Oxley, E., ... & Siemens, G. (2024). A meta systematic review of artificial intelligence in higher education: A call for increased ethics, collaboration, and rigour. *International Journal of Educational Technology in Higher Education*, 21(1), 4. <https://doi.org/10.1186/s41239-023-00436-z>
- Carolus, A., Koch, M. J., Straka, S., Latoschik, M. E., & Wienrich, C. (2023). MAILS-Meta AI literacy scale: Development and testing of an AI literacy questionnaire based on well-founded competency models and psychological change-and meta-competencies. *Computers in Human Behavior: Artificial Humans*, 1(2), 100014. <https://doi.org/10.1016/j.chbah.2023.100014>
- Chen, L., Chen, P., & Lin, Z. (2020). Artificial intelligence in education: A review. *IEEE Access*, 8, 75264–75278. <https://doi.org/10.1109/access.2020.2988510>
- Chiu, T. K. F., Moorhouse, B. L., Chai, C. S., & Ismailov, M. (2023). Teacher supports and student motivation to learn with artificial intelligence (AI) based chatbot. *Interactive Learning Environments*, 1–17. <https://doi.org/10.1080/10494820.2023.2172044>
- Chiu, T. K., Ahmad, Z., Ismailov, M., & Sanusi, I. T. (2024). What is artificial intelligence, literacy and competency? A comprehensive framework to support them. *Computers and Education Open*, 6, 100171. <https://doi.org/10.1016/j.caeo.2024.100171>
- Cirneanu, A. L., & Moldoveanu, C. E. (2024). Use of digital technology in integrated mathematics education. *Applied System Innovation*, 7(4), 66. <https://doi.org/10.3390/asi7040066>
- Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science*, 35(8), 982–1003. <https://doi.org/10.1287/mnsc.35.8.982>
- Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2010). Teacher technology changes: How knowledge, confidence, beliefs, and culture intersect. *Journal of Research on Technology in Education*, 42(3), 255–284. <https://doi.org/10.1080/15391523.2010.10782551>
- Falloon, G. (2020). From digital literacy to digital competence: The teacher digital competency (TDC) framework. *Educational Technology Research and Development*, 68(5), 2449–2472. <https://doi.org/10.1007/s11423-020-09767-4>
- Garlinska, M., Osial, M., Proniewska, K., & Pregowska, A. (2023). The influence of emerging technologies on distance education. *Electronics*, 12(7), 1550. <https://doi.org/10.3390/electronics12071550>
- Geraniou, E., & Jankvist, U. T. (2019). Towards a definition of “mathematical digital competency”. *Educational Studies in Mathematics*, 102(1), 29–45. <https://doi.org/10.1007/s10649-019-09893-8>
- Guan, C., Mou, J., & Jiang, Z. (2020). Artificial intelligence innovation in education: A twenty-year data-driven historical analysis. *International Journal of Innovation Studies*, 4(4), 134–147. <https://doi.org/10.1016/j.ijis.2020.09.001>
- 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>
- Hasibuan, N. S., & Lubis, M. S. (2024). The influence of digital literacy and learning styles on students' mathematics learning outcomes. *Unnes Journal of Mathematics Education*, 13(1), 36–45.
- Hatlevik, O. E., Guðmundsdóttir, G. B., & Loi, M. (2015). Digital diversity among upper secondary students: A multilevel analysis of the relationship between cultural

- capital, self-efficacy, strategic use of information and digital competence. *Computers & Education*, 81, 345–353. <https://doi.org/10.1016/j.compedu.2014.10.019>
- Huang, X. (2021). Aims for cultivating students' key competencies based on artificial intelligence education in China. *Education and Information Technologies*, 26(5), 5127–5147. <https://doi.org/10.1007/s10639-021-10530-2>
- Huang, X., Craig, S. D., Xie, J., Graesser, A., & Hu, X. (2016). Intelligent tutoring systems work as a math gap reducer in 6th grade after-school program. *Learning and Individual Differences*, 47, 258–265. <https://doi.org/10.1016/j.lindif.2016.01.012>
- Hur, J. W. (2025). Fostering AI literacy: Overcoming concerns and nurturing confidence among preservice teachers. *Information and Learning Sciences*, 126(1/2), 56–74. <https://doi.org/10.1108/ILS-11-2023-0170>
- Illomäki, L., Paavola, S., Lakkala, M., & Kantosalo, A. (2016). Digital competence—An emergent boundary concept for policy and educational research. *Education and Information Technologies*, 21, 655–679. <https://doi.org/10.1007/s10639-014-9346-4>
- Jarke, J., & Breiter, A. (2019). The datafication of education. *Learning, Media and Technology*, 44(1), 1–6. <https://doi.org/10.1080/17439884.2019.1573833>
- Kaswan, K. S., Dhatterwal, J. S., & Ojha, R. P. (2024). AI in personalized learning. In *Advances in technological innovations in higher education* (pp. 103–117). CRC Press. <https://doi.org/10.1201/9781003376699-9>
- Kim, K., & Kwon, K. (2023). Exploring the AI competencies of elementary school teachers in South Korea. *Computers and Education: Artificial Intelligence*, 4, 100137. <https://doi.org/10.1016/j.caeai.2023.100137>
- Kim, S., Jang, Y., Kim, W., Choi, S., Jung, H., Kim, S., & Kim, H. (2021, May). Why and what to teach: AI curriculum for elementary school. In *Proceedings of the AAAI Conference on Artificial Intelligence*, 35(17), 15569–15576. <https://doi.org/10.1609/aaai.v35i17.17833>
- Kong, S. C., Cheung, W. M. Y., & Zhang, G. (2021). An evaluation of an artificial intelligence literacy course for university students with diverse study backgrounds. *Computers and Education: Artificial Intelligence*, 2, 100026. <https://doi.org/10.1016/j.caeai.2021.100026>
- Kousa, P., & Niemi, H. (2023). AI ethics and learning: EdTech companies' challenges and solutions. *Interactive Learning Environments*, 31(10), 6735–6746. <https://doi.org/10.1080/10494820.2022.2043908>
- Lim, E. M. (2023). The effects of pre-service early childhood teachers' digital literacy and self-efficacy on their perception of AI education for young children. *Education and Information Technologies*, 28(10), 12969–12995. <https://doi.org/10.1007/s10639-023-11724-6>
- Long, D., & Magerko, B. (2020, April). What is AI literacy? Competencies and design considerations. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (pp. 1–16). <https://doi.org/10.1145/3313831.3376727>
- Lorenz, U., & Romeike, R. (2023, October). What is AI-PACK? – Outline of AI competencies for teaching with DPACK. In *International Conference on Informatics in Schools: Situation, Evolution, and Perspectives* (pp. 13–25). Springer Nature Switzerland. [https://doi.org/10.1007/978-3-031-44900-0\\_2](https://doi.org/10.1007/978-3-031-44900-0_2)
- Lucas, M., Bem-haja, P., Zhang, Y., Llorente-Cejudo, C., & Palacios-Rodríguez, A. (2025). A comparative analysis of pre-service teachers' readiness for AI integration. *Computers and Education: Artificial Intelligence*, 8, 100396. <https://doi.org/10.1016/j.caeai.2025.100396>
- Mandal, S., & Naskar, S. K. (2021). Classifying and solving arithmetic math word problems—An intelligent math solver. *IEEE Transactions on Learning Technologies*, 14(1), 28–41. <https://doi.org/10.1109/TLT.2021.3057805>

- Markauskaite, L., Marrone, R., Poquet, O., Knight, S., Martinez-Maldonado, R., Howard, S., ... & Siemens, G. (2022). Rethinking the entwining between artificial intelligence and human learning: What capabilities do learners need for a world with AI? *Computers and Education: Artificial Intelligence*, 3, 100056. <https://doi.org/10.1016/j.caeai.2022.100056>
- Monteiro, A., & Leite, C. (2021). Digital literacies in higher education: Skills, uses, opportunities and obstacles to digital transformation. *Revista de Educación a Distancia (RED)*, 21(65). <https://doi.org/10.6018/red.438721>
- Ng, D. T. K., Leung, J. K. L., Chu, S. K. W., & Qiao, M. S. (2021). Conceptualizing AI literacy: An exploratory review. *Computers and Education: Artificial Intelligence*, 2, 100041. <https://doi.org/10.1016/j.caeai.2021.100041>
- Ng, D. T. K., Leung, J. K. L., Su, J., Ng, R. C. W., & Chu, S. K. W. (2023). Teachers' AI digital competencies and twenty-first century skills in the post-pandemic world. *Educational Technology Research and Development*, 71(1), 137–161. <https://doi.org/10.1007/s11423-023-10203-6>
- Ning, Y., Zhang, C., Xu, B., Zhou, Y., & Wijaya, T. T. (2024). Teachers' AI-TPACK: Exploring the relationship between knowledge elements. *Sustainability*, 16(3), 978. <https://doi.org/10.3390/su16030978>
- Ning, Y., Zhang, W., Yao, D., Fang, B., Xu, B., & Wijaya, T. T. (2025). Development and validation of the Artificial Intelligence Literacy Scale for Teachers (AILST). *Education and Information Technologies*, 1–35. <https://doi.org/10.1007/s10639-025-13347-5>
- Ning, Y., Zhou, Y., Wijaya, T. T., & Chen, J. (2022). Teacher education interventions on teacher TPACK: A meta-analysis study. *Sustainability*, 14(18), 11791. <https://doi.org/10.3390/su141811791>
- OpenAI. (2023). *ChatGPT* (Mar 14 version) [Large language model]. <https://chat.openai.com/chat>
- Pane, J. F., Steiner, E. D., Baird, M. D., Hamilton, L. S., & Pane, J. D. (2017). *Informing progress: Insights on personalized learning implementation and effects*. Research Report RR-2042-BMGF. RAND Corporation. <https://doi.org/10.7249/RR2042>
- Pinski, M., & Benlian, A. (2023). AI literacy – Towards measuring human competency in artificial intelligence. *AIS Transactions on Human-Computer Interaction*, 15(3), 1–25. Retrieved from <https://aisel.aisnet.org/thci/vol15/iss3/1/>
- Poquet, O., & De Laat, M. (2021). Developing capabilities: Lifelong learning in the age of AI. *British Journal of Educational Technology*, 52(4), 1695–1708. <https://doi.org/10.1111/bjet.13123>
- Rafi, M., JianMing, Z., & Ahmad, K. (2019). Technology integration for students' information and digital literacy education in academic libraries. *Information Discovery and Delivery*, 47(4), 203–217. <https://doi.org/10.1108/IDD-07-2019-0049>
- Sattelmaier, L., & Pawlowski, J. M. (2023, October). Towards a generative artificial intelligence competence framework for schools. In A. Gunawan, R. Andriani, & D. Ardiansyah (Eds.), *Proceedings of the International Conference on Enterprise and Industrial Systems (ICOEINS 2023)*. 270, pp. 291–298. Springer Nature. [https://doi.org/10.2991/978-94-6463-340-5\\_26](https://doi.org/10.2991/978-94-6463-340-5_26)
- Sing, C. C., Teo, T., Huang, F., Chiu, T. K., & Wei, W. X. (2022). Secondary school students' intentions to learn AI: Testing moderation effects of readiness, social good and optimism. *Educational Technology Research and Development*, 70(3), 765–782. <https://doi.org/10.1007/s11423-022-10111-1>
- Spante, M., Hashemi, S. S., Lundin, M., & Algers, A. (2018). Digital competence and digital literacy in higher education research: Systematic review of concept use. *Cogent Education*, 5(1), 1519143. <https://doi.org/10.1080/2331186X.2018.1519143>

- Teo, T., Zhou, M., Fan, A. C. W., & Huang, F. (2019). Factors that influence university students' intention to use Moodle: A study in Macau. *Educational Technology Research and Development*, 67, 749–766. <https://doi.org/10.1007/s11423-019-09650-x>
- Tondeur, J., Van Braak, J., Ertmer, P. A., & Ottenbreit-Leftwich, A. (2017). Understanding the relationship between teachers' pedagogical beliefs and technology use in education: A systematic review of qualitative evidence. *Educational Technology Research and Development*, 65, 555–575. <https://doi.org/10.1007/s11423-016-9481-2>
- Touretzky, D., Gardner-McCune, C., Martin, F., & Seehorn, D. (2019). Envisioning AI for K-12: What should every child know about AI? *Proceedings of the AAAI Conference on Artificial Intelligence*, 33(1), 9795–9799. <https://doi.org/10.1609/aaai.v33i01.33019795>
- Viberg, O., Grönlund, Å., & Andersson, A. (2023). Integrating digital technology in mathematics education: A Swedish case study. *Interactive Learning Environments*, 31(1), 232–243. <https://doi.org/10.1080/10494820.2020.1770801>
- Voogt, J., Fisser, P., Good, J., Mishra, P., & Yadav, A. (2015). Computational thinking in compulsory education: Towards an agenda for research and practice. *Education and Information Technologies*, 20, 715–728. <https://doi.org/10.1007/s10639-015-9412-6>
- Wang, B., Rau, P. L. P., & Yuan, T. (2023). Measuring user competence in using artificial intelligence: Validity and reliability of artificial intelligence literacy scale. *Behaviour & Information Technology*, 42(9), 1324–1337. <https://doi.org/10.1080/0144929X.2022.2072768>
- Wang, W. S., Lin, C. J., Lee, H. Y., Huang, Y. M., & Wu, T. T. (2025). Integrating feedback mechanisms and ChatGPT for VR-based experiential learning: Impacts on reflective thinking and AIoT physical hands-on tasks. *Interactive Learning Environments*, 33(2), 1770–1787. <https://doi.org/10.1080/10494820.2024.2375644>
- Yang, J. (2025). Research on the correlation between college students' use of large language models and AI digital literacy. In C. Barstow & H. Briel (Eds.), *Connecting Ideas, Cultures, and Communities* (pp. 516–522). Routledge.
- Yang, W. (2022). Artificial intelligence education for young children: Why, what, and how in curriculum design and implementation. *Computers and Education: Artificial Intelligence*, 3, 100061. <https://doi.org/10.1016/j.caeai.2022.100061>
- Yuan, Z., Liu, J., Deng, X., Ding, T., & Wijaya, T. (2023). Facilitating conditions as the biggest factor influencing elementary school teachers' usage behavior of dynamic mathematics software in China. *Mathematics*, 11(6), 1536. <https://doi.org/10.3390/math11061536>
- Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education—Where are the educators? *International Journal of Educational Technology in Higher Education*, 16(1), Article 1. <https://doi.org/10.1186/s41239-019-0171-0>
- Zhang, C., Schießl, J., Plössl, L., Hofmann, F., & Gläser-Zikuda, M. (2023). Acceptance of artificial intelligence among pre-service teachers: A multigroup analysis. *International Journal of Educational Technology in Higher Education*, 20(1), 49. <https://doi.org/10.1186/s41239-023-00420-7>
- Zhang, H., Lee, I., Ali, S., DiPaola, D., Cheng, Y., & Breazeal, C. (2023). Integrating ethics and career futures with technical learning to promote AI literacy for middle school students: An exploratory study. *International Journal of Artificial Intelligence in Education*, 33(2), 290–324. <https://doi.org/10.1007/s40593-022-00293-3>

- Zhao, L., Wu, X., & Luo, H. (2022). Developing AI literacy for primary and middle school teachers in China: Based on a structural equation modeling analysis. *Sustainability*, *14*(21), 14549. <https://doi.org/10.3390/su142114549>
- Zhao, Y., Llorente, A. M. P., & Gómez, M. C. S. (2021). Digital competence in higher education research: A systematic literature review. *Computers & Education*, *168*, 104212. <https://doi.org/10.1016/j.compedu.2021.104212>