Digital Literacy and Higher-Order Thinking Skills of Pre-Service Physics Teachers in Artificial Intelligence-Based Learning Management Systems

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***Abstract**: This study aimed to investigate the levels of digital literacy and higher-order thinking skills (HOTS) among pre-service physics teachers in Artificial Intelligence (AI)-based Learning Management Systems (LMS). A descriptive quantitative approach was employed involving 54 fifth-semester students of the Physics Education Study Program, Faculty of Teacher Training and Education, University of Mataram, during the 2025/2026 academic year. Data were collected throughout the learning process from August to October 2025. The research instruments consisted of a HOTS test comprising five essay questions scored on a scale of 0–4 and a digital literacy questionnaire consisting of 36 items measured using a five-point Likert scale. The data were converted into percentages and analyzed using descriptive statistics and Spearman's rho correlation. The results revealed that the mean HOTS score was 78.43, categorized as high, while the mean digital literacy score was 83.28, categorized as very high. HOTS scores ranged from 65.00 to 90.00, whereas digital literacy scores ranged from 72.00 to 95.00. Spearman's rho analysis indicated a very strong positive correlation between HOTS and digital literacy ($\rho = 0.941$, $p < 0.001$). These findings suggest that higher levels of digital literacy are associated with better higher-order thinking skills among pre-service physics teachers in AI-based LMS environments.*

Keywords: Digital literacy, HOTS, LMS, Artificial intelligence

Abstrak: Penelitian ini bertujuan untuk menyelidiki tingkat literasi digital dan keterampilan berpikir tingkat tinggi (HOTS) di kalangan calon guru fisika dalam Sistem Manajemen Pembelajaran (LMS) berbasis Kecerdasan Buatan (AI). Pendekatan kuantitatif deskriptif digunakan dengan melibatkan 54 mahasiswa semester lima Program Studi Pendidikan Fisika, Fakultas Keguruan dan Ilmu Pendidikan, Universitas Mataram, selama tahun akademik 2025/2026. Data dikumpulkan sepanjang proses pembelajaran dari Agustus hingga Oktober 2025. Instrumen penelitian terdiri dari tes HOTS yang terdiri dari lima pertanyaan esai yang diberi skor pada skala 0–4 dan kuesioner literasi digital yang terdiri dari 36 item yang diukur menggunakan skala Likert lima poin. Data dikonversi menjadi persentase dan dianalisis menggunakan statistik deskriptif dan korelasi rho Spearman. Hasil penelitian menunjukkan bahwa skor rata-rata HOTS adalah 78,43, dikategorikan tinggi, sedangkan skor rata-rata literasi digital adalah 83,28, dikategorikan sangat tinggi. Skor HOTS berkisar antara

65,00 hingga 90,00, sedangkan skor literasi digital berkisar antara 72,00 hingga 95,00. Analisis rho Spearman menunjukkan korelasi positif yang sangat kuat antara HOTS dan literasi digital ($\rho = 0,941$, $p < 0,001$). Temuan ini menunjukkan bahwa tingkat literasi digital yang lebih tinggi dikaitkan dengan keterampilan berpikir tingkat tinggi yang lebih baik di antara calon guru fisika dalam lingkungan LMS berbasis AI.

Kata kunci: Literasi digital, HOTS, LMS, Kecerdasan buatan

INTRODUCTION

The rapid advancement of digital technology has significantly transformed educational practices worldwide. The integration of digital tools into teaching and learning processes has become essential for preparing students to meet the demands of the twenty-first century. Among the various technological innovations adopted in education, Learning Management Systems (LMS) have emerged as an important platform for facilitating learning activities, communication, collaboration, assessment, and resource management. More recently, the incorporation of Artificial Intelligence (AI) into LMS environments has created new opportunities for personalized learning, adaptive feedback, intelligent content delivery, and enhanced learner engagement (Lahanika et al., 2026; Gligorea et al., 2023).

The growing use of AI-based LMS environments requires students to possess adequate digital competencies to effectively access, evaluate, and utilize digital information. Digital literacy has therefore become one of the most important competencies in contemporary education. Digital literacy extends beyond the ability to operate digital devices; it also includes the capacity to access, analyze, evaluate, create, and communicate information responsibly through digital technologies. In higher education, digital literacy is increasingly recognized as a critical factor influencing students' academic performance, self-directed learning, and readiness to participate in technology-rich learning environments (Hayatullah et al., 2026; Zai et al., 2020).

In addition to digital literacy, Higher-Order Thinking Skills (HOTS) are considered fundamental competencies for the twenty-first century. HOTS involve advanced cognitive processes such as analyzing, evaluating, and creating, which correspond to the upper levels of Bloom's revised taxonomy. These skills enable learners to solve complex problems, make informed decisions, and generate innovative solutions. For pre-service teachers, HOTS are particularly important because future educators are expected not only to master subject knowledge but also to foster critical and creative thinking among their students (Yorman, 2024; Febrianti & Fazalani, 2026).

Pre-service physics teachers face unique challenges in developing both digital literacy and HOTS. As future educators, they are expected to integrate technology effectively into science instruction while simultaneously promoting higher-order thinking among learners (Suniati et al., 2026). The increasing adoption of AI-powered educational technologies further emphasizes the need for pre-service teachers to develop competencies that support effective teaching and learning in digital environments. Consequently, teacher education programs must ensure that students acquire sufficient digital literacy and higher-order thinking skills before entering the teaching profession (Romli et al., 2026; Yetti & Ahyanuardi, 2020).

Previous studies have reported that technology-enhanced learning environments can contribute positively to students' digital competencies, critical thinking, and academic achievement. The integration of LMS platforms and AI tools has been associated with increased learner engagement, improved access to learning resources, and greater opportunities for independent learning. However, the extent to which digital literacy is associated with HOTS among pre-service teachers remains an important area for investigation, particularly within AI-based learning environments (Khairkhah et al., 2026; Hikmawati et al., 2025).

At the Physics Education Study Program of the University of Mataram, AI-based LMS platforms have been integrated into several courses, including School Administration and Management. Through these learning environments, students engage in online discussions, access digital learning resources, complete assignments, and utilize AI-supported tools to support their learning activities. Such experiences provide opportunities for students to develop both digital literacy and higher-order thinking skills (Sirajuddin et al., 2026; Qadri et al., 2026).

Despite the increasing implementation of AI-based LMS environments in higher education, empirical evidence regarding the levels of digital literacy and HOTS among pre-service physics teachers remains limited. Furthermore, understanding the relationship between these two competencies is essential for designing effective learning strategies that prepare future teachers for the challenges of digital education. Therefore, this study aims to investigate the levels of digital literacy and higher-order thinking skills among pre-service physics teachers in Artificial Intelligence-based Learning Management Systems and to examine the relationship between these two variables (Hikmawati, Doyan, et al., 2024; Hikmawati, Suastra, et al., 2024).

METHOD

This study employed a quantitative descriptive research design to investigate the levels of digital literacy and Higher-Order Thinking Skills (HOTS) among pre-service physics teachers in Artificial Intelligence (AI)-based Learning Management Systems (LMS). The study was conducted in the Physics Education Study Program, Faculty of Teacher Training and Education, University of Mataram, during the odd semester of the 2025/2026 academic year. The participants consisted of 54 fifth-semester students enrolled in the School Administration and Management course. Learning activities were conducted through an AI-based LMS environment that integrated various digital learning resources and AI-supported applications. Data collection was conducted throughout the mid-semester learning period, from August to October 2025 (Creswell, 2012).

Two research instruments were used in this study. The first instrument was a HOTS test consisting of five essay questions developed based on the higher cognitive levels of Bloom's revised taxonomy, namely analyzing (C4), evaluating (C5), and creating (C6). The test covered five topics: Fundamental Concepts of School Management and Administration, Educational Organizations, Curriculum and Learning Management, Student Management, and Management of Educators and Educational Personnel. Each question was assessed using a scoring rubric ranging from 0 to 4, where 0 indicated no response and 4 indicated a comprehensive, logical, critical, and innovative response. The maximum HOTS score was 20 (Krathwohl, 2017).

The second instrument was a digital literacy questionnaire consisting of 36 statements measured using a five-point Likert scale ranging from strongly disagree (1) to strongly agree (5). The questionnaire was developed based on six dimensions of digital literacy: (1) accessing and using digital technologies, (2) understanding and evaluating digital information, (3) critical thinking in digital environments, (4) digital communication and collaboration, (5) digital creativity and content production, and (6) digital ethics and security. The minimum possible score of the questionnaire was 36, while the maximum possible score was 180 (Likert, 1932).

The HOTS and digital literacy scores were converted into percentages to facilitate interpretation and comparison. HOTS scores were calculated using Equation (1):

$$HOTS\ Score = \frac{Obtained\ Score}{20} x100$$

Digital literacy scores were calculated using Equation (2):

$$Digital\ Literacy\ Score = \frac{Obtained\ Score}{180} x100$$

Descriptive statistics, including minimum score, maximum score, mean, and standard deviation, were used to describe the levels of HOTS and digital literacy. Prior to correlation analysis, normality tests were performed using the Kolmogorov–Smirnov and Shapiro Wilk tests. The results indicated that the HOTS data were not normally distributed; therefore, the relationship between HOTS and digital literacy was analyzed using Spearman's rho correlation. All statistical analyses were conducted using SPSS version 25.

To interpret the levels of HOTS and digital literacy, percentage scores were classified into five categories as presented in Table 1.

Table 1. Interpretation of HOTS and Digital Literacy Scores

Percentage (%)	Category
81–100	Very High
61–80	High
41–60	Moderate
21–40	Low
0–20	Very Low

RESULTS AND DISCUSSION

Descriptive Statistics of Higher-Order Thinking Skills and Digital Literacy

The descriptive statistics of Higher-Order Thinking Skills (HOTS) and Digital Literacy among pre-service physics teachers are presented in Table 2.

Table 2. Descriptive Statistics of HOTS and Digital Literacy

Variable	N	Minimum	Maximum	Mean	Standard Deviation
Higher-Order Thinking Skills	54	65.00	90.00	78.43	8.00
Digital Literacy	54	72.00	95.00	83.28	7.33

As shown in Table 2, the mean HOTS score was 78.43, indicating a high level of higher-order thinking skills among the participants. The scores ranged from 65.00 to 90.00, with a standard deviation of 8.00, suggesting moderate variability among students. These findings indicate that most pre-service physics teachers were able to demonstrate analytical, evaluative, and problem-solving abilities in the context of school administration and management. Meanwhile, the mean digital literacy score reached 83.28, which falls into the very high category. The scores ranged from 72.00 to 95.00 with a standard deviation of 7.33, indicating that students generally possessed strong digital competencies and were able to effectively utilize digital technologies in learning activities.

The comparison of the mean scores reveals that digital literacy was slightly higher than HOTS. This finding suggests that students are generally more proficient in accessing and utilizing digital technologies than in applying advanced cognitive skills such as analysis, evaluation, and creation. Although both variables were categorized as high, the results indicate that the development of HOTS still requires greater attention in higher education learning environments.

Distribution of HOTS and Digital Literacy Scores

The distribution of HOTS scores is illustrated in Figure 1.

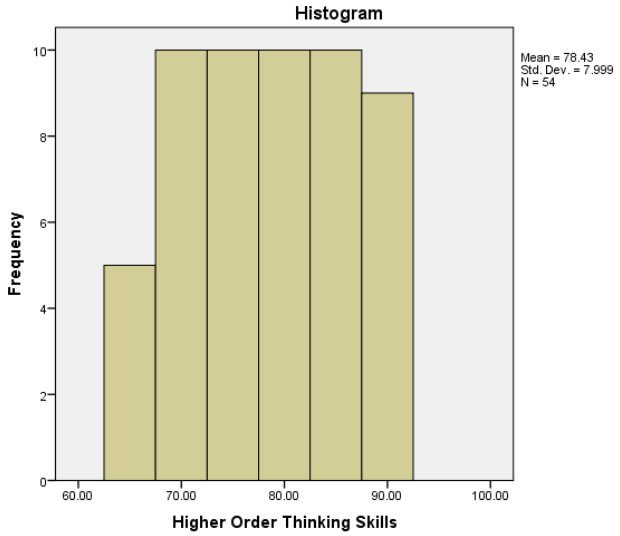

Figure 1. Histogram of Higher-Order Thinking Skills (HOTS)

The histogram of HOTS scores shows that most students scored between 70 and 90, with the highest concentration around the mean of 78.43. The distribution demonstrates that the majority of participants possessed relatively strong higher-order thinking abilities, while only a few students obtained lower scores. The absence of extreme scores indicates that the learning process provided relatively equal opportunities for students to develop analytical and evaluative thinking skills. Overall, the distribution confirms that HOTS among pre-service physics teachers was generally high and relatively consistent across the sample.

The distribution of digital literacy scores is presented in Figure 2.

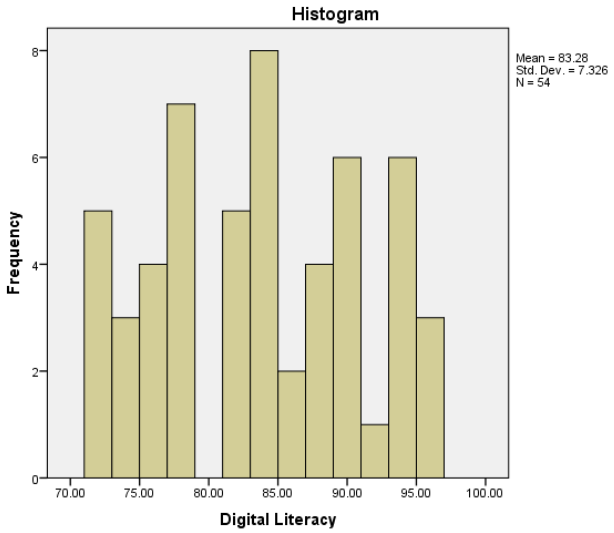

Figure 2. Histogram of Digital Literacy

The histogram of digital literacy scores indicates that the majority of students achieved scores above 80, with scores ranging from 72 to 95. The mean score of 83.28 demonstrates that students possessed very high levels of digital literacy. Although the distribution is not perfectly symmetrical, the scores are concentrated within the upper range, suggesting that most students were highly familiar with digital technologies and online learning environments. The relatively moderate standard deviation further indicates that digital literacy competencies were fairly evenly distributed among the participants. These results suggest that students were well prepared to engage in technology-enhanced learning and effectively utilize AI-supported educational tools.

Normality Test Results

Prior to the correlation analysis, normality tests were conducted using the Kolmogorov–Smirnov and Shapiro–Wilk tests. The results are presented in Table 3.

Table 3. Results of Normality Tests

Variable	Kolmogorov–Smirnov Sig.	Shapiro–Wilk Sig.
Higher-Order Thinking Skills	0.006	0.001
Digital Literacy	0.066	0.009

The normality test results indicate that the HOTS data were not normally distributed ($p < 0.05$). Although the digital literacy variable met the normality assumption based on the Kolmogorov–Smirnov test, the non-normal distribution of HOTS led to the use of a nonparametric statistical technique. Therefore, Spearman's rho correlation was selected to examine the relationship between HOTS and digital literacy.

Relationship between HOTS and Digital Literacy

The relationship between HOTS and digital literacy was analyzed using Spearman's rho correlation. The results are presented in Table 4.

Table 4. Spearman's rho Correlation between HOTS and Digital Literacy

Variables	Correlation Coefficient (ρ)	Sig. (2-tailed)	N
HOTS – Digital Literacy	0.941	0.000	54

The results revealed a very strong positive correlation between HOTS and digital literacy ($\rho = 0.941$, $p < 0.001$). This finding indicates that students with higher levels of digital literacy tended to demonstrate higher levels of HOTS. The significance value confirms that the relationship between the two variables is statistically significant.

The strong relationship between digital literacy and HOTS can be explained by the nature of learning activities in AI-based Learning Management Systems. Students with better digital literacy are generally more capable of accessing information, evaluating the credibility of digital resources, managing online learning activities, and utilizing digital tools effectively. These competencies support higher-order cognitive processes such as analyzing information, evaluating alternatives, and generating solutions to complex problems. Consequently, digital literacy serves as an important foundation for the development of HOTS in technology-rich learning environments (Ouyang & Jiao, 2021; Chiu & Chai, 2020).

The findings of this study also highlight the educational value of Learning Management Systems in higher education. LMS platforms provide students with continuous access to learning materials, discussion forums, online assessments, and collaborative learning opportunities. Through these features, students are encouraged to engage in independent learning and knowledge construction rather than merely receiving information passively. Such learning experiences contribute to the development of critical thinking and problem-solving skills, which are essential components of HOTS (Hwang, 2020; Luan et al., 2020).

Furthermore, the integration of Artificial Intelligence into LMS environments may strengthen students' cognitive engagement. AI-supported tools can provide personalized feedback, recommend relevant learning resources, facilitate information retrieval, and assist students in organizing knowledge more efficiently. These capabilities allow students to focus more on higher-order cognitive activities, including analysis, evaluation, and synthesis of information. As a result, AI has the potential to function not only as a technological support tool but also as a catalyst for developing advanced thinking skills (Yang, 2022; Wong et al., 2020).

From the perspective of teacher education, the findings are particularly important because pre-service physics teachers are expected to become future educators who can effectively integrate technology into classroom instruction. The ability to use AI-based technologies responsibly and critically is increasingly recognized as an essential professional competency. Teachers who possess strong digital literacy are more likely to design innovative learning experiences, evaluate digital resources critically, and facilitate students' higher-order thinking development (Azhari et al., 2026); (Fahimirad, 2018).

The very high level of digital literacy observed in this study indicates that students are generally prepared to participate in digital learning environments. However, the slightly lower HOTS scores suggest that technology use alone is insufficient to maximize higher-order thinking development. Effective instructional strategies remain necessary to encourage students to engage in inquiry, reflection, argumentation, and problem-solving activities. Therefore, future learning designs should combine the technological advantages of LMS and AI with pedagogical approaches that explicitly promote HOTS (Putri, 2026; Fahimirad, 2018).

Overall, the findings suggest that AI-based Learning Management Systems can play a significant role in supporting both digital literacy and higher-order thinking skills among pre-service physics teachers. The strong relationship between these variables underscores the importance of integrating digital literacy development into teacher education curricula to prepare future educators for the challenges and opportunities of twenty-first-century education (Tedre et al., 2021; Zhai et al., 2021).

CONCLUSION

The findings indicate that pre-service physics teachers demonstrated a high level of Higher-Order Thinking Skills (HOTS) and a very high level of digital literacy in Artificial Intelligence (AI)-based Learning Management Systems (LMS). Furthermore, a very strong positive correlation was found between digital literacy and HOTS, suggesting that students with stronger digital literacy tend to possess better higher-order thinking abilities. These results highlight the important role of digital literacy in supporting the development of HOTS within technology-enhanced learning environments.

Based on these findings, educators and teacher education programs are encouraged to optimize the use of AI-based LMS platforms through learning activities that promote critical thinking, problem-solving, collaboration, and independent learning. Future studies are recommended to involve larger and more diverse samples and to examine additional factors that may influence digital literacy and HOTS in order to provide a more comprehensive understanding of these competencies in teacher education.

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