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AI (Artificial Intelligence)-Enhanced Digital Literacy in Science Learning: A Systematic Literature Review

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ABSTRACT

The need to understand AI in education is increasingly pressing along with developments in the digital era. This study aims to systematically examine how AI is used in science learning to improve students' digital literacy, and to identify the most effective approaches based on recent empirical studies. The study was conducted using the Systematic Literature Review method of articles published in 2021–2025 that focus on the integration of AI in science education and the development of digital literacy. Selection was carried out through a process of identification, screening, and full-text evaluation with PRISMA guidelines. The results of the article extraction obtained 10 articles that met the criteria. The results of the review show that AI is used in various forms, such as Solar System Scope, virtual laboratories, and data-based quiz platforms. This AI-integrated platform supports the development of digital literacy in terms of information navigation, scientific visual interpretation, self-learning reflection, and responsible use of technology. Thus, the integration of AI in science learning has great potential in shaping students' digital literacy more meaningfully. The success of this approach is greatly influenced by pedagogical design, active student involvement, and the suitability of the technological context to learning objectives.

1. Introduction

Science learning is very important role in shaping students' understanding of the natural world and developing essential cognitive skills, such as critical thinking and analytical skills (Yanti et al., 2024). However, science learning often faces various challenges that hinder its effectiveness. One of the main challenges is the abstract nature of many science concepts, which are often difficult for students who are still in the early stages of cognitive development to understand. Natural phenomena that cannot be observed directly, as well as the need to conduct complex experiments, are obstacles to creating deep and sustainable understanding in students (Aini et al., 2024; Ansya et al., 2025).

Along with the development of technology, the integration of Artificial Intelligence (AI) in science learning offers significant potential to improve students' learning experiences through a more interactive, personalized, and adaptive approach (Yılmaz, 2024). The application of Artificial Intelligence in science learning opens up extraordinary opportunities to address classic challenges such as low learning motivation, difficulty understanding abstract concepts, and limitations in conventional learning. Through technologies such as Solar System Scope, SkySafari, and Virtual Laboratory, students can now get real-time feedback and personalized guidance that previously could only be provided by teachers directly (Agrawal et al., 2024; Rane et al., 2023).

The need to understand the impact of AI in education is increasingly urgent as global data from UNESCO (2024) notes that 70% of educational institutions in the world have begun implementing AI-based technology, but only 42% of educators feel they have the pedagogical skills to optimally utilize it in the classroom (Zaini et al., 2025). This is supported by the measurement results report.digital literacy indexIndonesia in 2022 released by the Ministry of Communication and Informatics (KEMENKOMINFO) together with the Katadata Insight Center (KIC). According to the report, Indonesia's digital literacy index in 2022 was at level 3.54 points on a scale of 1-5 (Amaly & Armiah, 2021).

This means that in general the level of digital literacy of the Indonesian people is still at the "moderate" level. On the other hand, the lack of digital literacy skills is considered to have the potential to encourage consumer behavior of information without critical understanding, and even risk triggering technological dependence that reduces the quality of students' reflective thinking (Audrin & Audrin, 2022). Digital literacy not only includes basic skills in using information and communication technology devices, but also the ability to understand, manage, and evaluate digital information critically and responsibly.

Based on research conducted by Naamati-Schneider & Alt (2024), improving digital literacy skills is positively correlated with the effectiveness of using AI-based adaptive technology. Students with high levels of digital literacy are better able to navigate digital learning systems, explore adaptive features, and utilize learning recommendations provided by AI algorithms more optimally (Naamati-Schneider & Alt, 2024). Therefore, the development of digital literacy is not only a complement, but an essential requirement in the implementation of AI-based learning. Not only that, the use of AI also has many benefits in improving digital literacy skills.

In the context of science learning, the use of AI enables a more powerful experiential and interactive approach (Zhai, 2023). For example, through AI-based simulations, students can learn scientific phenomena such as planetary movements, chemical reactions, or energy flows in ecosystems in a visual and interactive way. This allows students to understand difficult concepts in a more engaging and meaningful way (Erduran, 2023; Ezzaim et al., 2024). In addition, AI can also help teachers design learning materials that are tailored to the individual needs of

students, making the learning process more efficient and inclusive (Yim & Su, 2025). Globally, the application of AI in education has shown promising results.

Research by Hooda et al. (2022) shows that the use of AI in learning can improve student learning outcomes by up to 20% compared to conventional methods. In developed countries, such as Finland, the United States, and Singapore, AI technology has been used to integrate science learning with digital technology, so that students not only learn about science but also build awareness of the importance of digital literacy in everyday technology use. Students who are accustomed to using AI technology in learning will be better prepared to face future challenges, both in the academic and professional worlds (Hooda et al., 2022). They are not only consumers of technology but are also able to understand, criticize, and utilize technology to solve real problems appropriately in accordance with the ethics of technology use.

However, the use of AI in education also has its drawbacks. Strielkowski & Grebennikova (2024) argue that AI is not a universal solution, and its use must be framed in the right pedagogical context (Strielkowski et al., 2024). In its use, synergy is needed between technology and the role of teachers as facilitators, not as total replacements. Learning that is too automated can actually eliminate the humanistic and interactive elements that are the main strengths in education (Gligorea et al., 2023).

The strength and novelty of this research lies in the focus of the analysis on student interactions with AI as a collaborative partner in the learning process, not just an information provider tool. This study aims to examine how AI can guide students in improving digital literacy skills, such as formulating data-based arguments, evaluating the credibility of digital information sources, and developing innovative solutions to learning problems amidst the abundant flow of information (Iskandar et al., 2025). This is in line with the needs of today's education world which places AI as a mediator in the development of literacy and complex thinking skills.

Based on the urgency and problems that have been described, this article is directed to analyze in depth the extent to which the integration of artificial intelligence in the learning process contributes to improving digital literacy in science learning. The findings of this study are expected to not only broaden the theoretical horizon regarding the role of AI in education, but also provide practical recommendations for the development of effective AI-based learning strategies in shaping the profile of 21st century learners who are adaptive, critical, and ethical.

2. Methodology

Research Design

This study adopts a qualitative approach by conducting a Systematic Literature Review method. Systematic literature review is a research approach that involves a systematic review of existing literature to answer specific research questions (Van

Dinter et al., 2021). In this study, the discussion focuses on the research objective, namely to examine empirical studies on how Artificial Intelligence (AI) is used to improve digital literacy in the context of science learning. To ensure that this research is carried out systematically, this study refers to the PRISMA 2020 guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). Furthermore, Zawacki-richter et al (2020) conveyed that the stages of the Systematic Literature Review research procedure can be described in the Figure 1.



Source: (Zawacki-Richter, 2021)

Figure 1. Systematic Literature Review Procedure Diagram

Data Collection

The literature search process was conducted on May 15, 2025 using the Science Direct and Google Scholar database sources. The search was conducted using the Harzing's Publish or Perish application. Table 1 shows the search strings used in the two databases.

Table 1. Search Strategy

Science Direct	Google Scholar
TITLE-ABS-KEY ("Artificial Intelligence", "Digital Literacy", and "Science Learning")	TITLE ("Artificial Intelligence (AI)" or "Artificial Intelligence", "Digital Literacy", and "Science Learning")

Source: Data Processing Results (2025).

Data Analysis

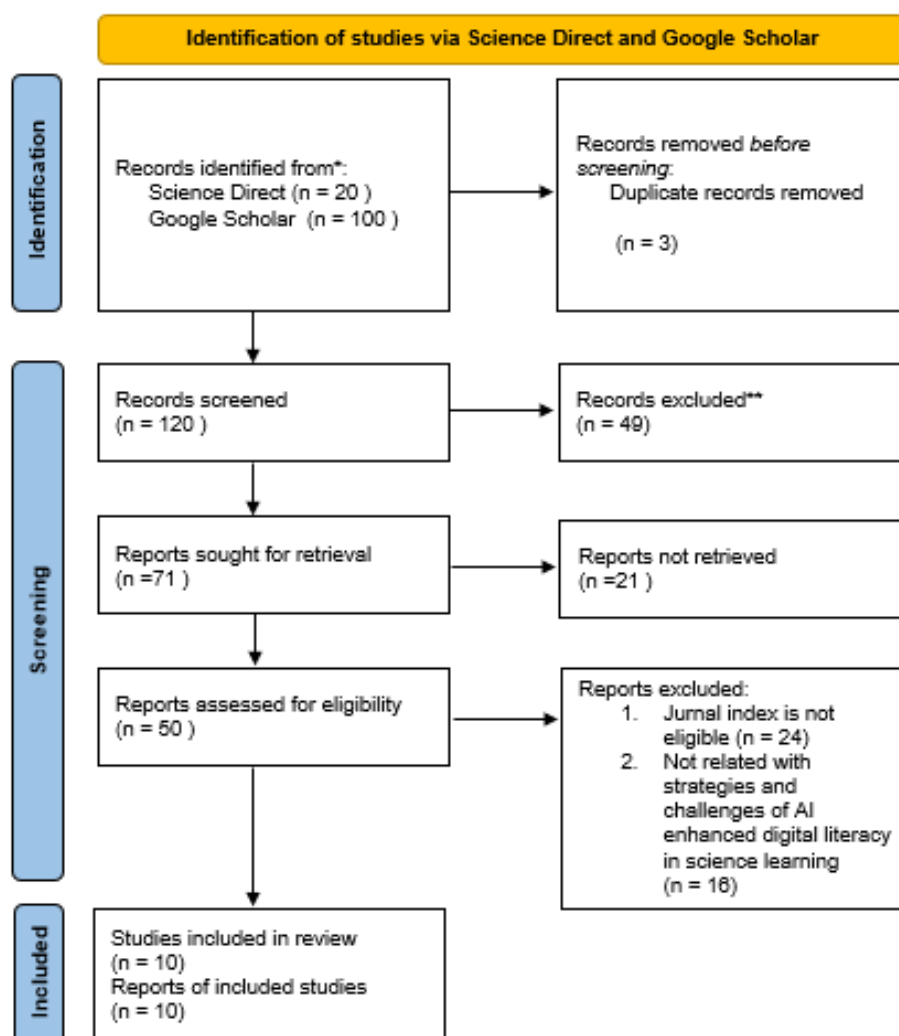
Each article found through relevant keywords was then evaluated based on the title, abstract, and keywords to determine whether the article was worthy of further analysis (Purboyo et al., 2025). Articles that met the inclusion criteria were then analyzed using a content analysis approach, where data was categorized based on several predetermined key indicators. After the articles were selected, the data extraction process was carried out with a focus on the following Research Questions:

RQ1 :How is AI used empirically to develop elements of digital literacy in the context of science learning?

RQ2 :What types and approaches of AI are most effective in shaping students' digital literacy competencies in science learning, based on empirical evidence?

The search results obtained 120 articles (Science Direct = 20 articles with a time span of 2021-2025 and Google Scholar = 100 articles with a time span of 2021-2025). Then, selection and evaluation were carried out to obtain relevant articles. The criteria for assessing the eligibility in the article extraction process are: (1) Published in the time span of 2021 to 2025, and indexed by Google Scholar and Scopus, (2) This article is a journal per review or proceedings, (3) Written content in either Indonesian or English, and (4) Content related to keywords.

In order for the selection and evaluation process to be more structured, the researcher used the Rayyan application for the selection process and the Microsoft Excel application for the coding, sorting, and data analysis processes. After going through a selection process that refers to the criteria, 10 out of 224 articles met the criteria. Prisma flow diagram in the Figure 2.



Source: Data Processing Results (2025).

Figure 2. PRISMA Flow Diagram

3. Result and Discussion

The results of an in-depth analysis of the articles that met the criteria showed that AI strategies and challenges as an enhancement of digital literacy in science learning can be seen in various forms, as explained below in the Table 2.

Table 2. Results of SLR PRISMA

No	Author (Year)	Title	AI Tools	Science Learning Context	The Role of Digital Literacy	Key Findings
1	Aggarwal (2023)	Integration of innovative technological developments and AI with education for an adaptive learning pedagogy.	Adaptive AI, NLP	Biology, High School	Adaptive feature navigation	Improved understanding of concepts (Aggarwal, 2023).
2	Yaseen et al. (2025)	The Impact of Adaptive Learning Technologies, Personalized Feedback, and Interactive AI Tools on Student Engagement: The Moderating Role of Digital Literacy.	AI feedback system	Physics, University	Moderating student engagement	Engagement increases in students with high digital literacy (Yaseen et al., 2025).
3	Ayeni et al. (2023)	Leveraging on AI-powered learning systems: Enhancing educational equity in digital classrooms.	Personalized tutoring	General science	Critical for inclusion	Low literacy = low participation (A. O. Ayeni et al., 2023).
4	Naamati-Schneider & Alt (2024)	Beyond digital literacy: The era of AI-powered assistants and evolving user skills	AI assistant, adaptive platform	General	Evolution of user skills	Digital literacy as capital for future competence (Naamati-Schneider & Alt, 2024).
5	A Alenezi (2024)	Evaluating the Effectiveness	Local adaptive system	Secondary school	Limiting factors for	The importance of teacher

No	Author (Year)	Title	AI Tools	Science Learning Context	The Role of Digital Literacy	Key Findings
		of AI-Powered Adaptive Learning Systems in Secondary Schools.			implementation	training and infrastructure (Alenezi, 2024).
6	Sumathy & Navamani (2024)	AI-Driven Personalized Learning: Enhancing Student Success through Adaptive Technologies.	AI recommendation system	Senior High School	Learning outcome mediator	Personal recommendations improve academic performance (Sumathy & Navamani, 2024).
7	Raza (2025)	Personalized Learning through AI: Opportunities and Challenges in Adaptive Educational Technologies.	Recommender system	Science exploration phase	Digital divide	Low literacy reduces effectiveness (Raza, 2025).
8	Strielkowski & Grebennikova (2024)	AI-driven adaptive learning for sustainable educational transformation	AI classifier	University	Not allowed to replace the teacher	Human-AI synergy is needed (Strielkowski et al., 2024).
9	Yigitalieva et al. (2024)	The Future of Literacy Education: Artificial Intelligence and Adaptive Learning Systems.	AI-literacy systems	Junior High School	Curriculum transformation	Standardization of AI teaching is needed (Yigitalieva et al., 2024).
10	Ayeni et al. (2024)	AI in education: A review of personalized learning and educational technology.	Adaptive ML	School Science	Ethics & access	AI could widen gaps without regulation (O. O. Ayeni et al., 2024).

In this research, there are two research questions that form the basis of the analysis in this article. The following is a discussion of each research question:

RQ1 : How is AI used empirically to develop elements of digital literacy in the context of science learning?

The use of Artificial Intelligence (AI) to develop digital literacy in science learning has become an increasingly important topic in empirical studies since 2021. Based on the analysis of 10 articles, the AI approach is used not only as a teaching aid, but also as a digital learning framework that is reflective, participatory, and personalized. Elements of digital literacy that are strengthened through AI include: critical thinking skills towards digital information, awareness of the ethics of technology use, technology-based collaboration, and understanding how AI itself works (AI literacy as a subdomain of digital literacy).

Several studies, such as by Su, Ng & Chu (2023), show how AI-based science learning platforms at the elementary school level encourage students to evaluate the quality of information through chatbot-based dialogues. Using the chatbot AI approach, students are invited to examine scientific statements, compare sources, and validate information in real-time, which is a direct practice of digital literacy in a scientific context (Su et al., 2023).

Another study by Stolpe & Hallström (2024) emphasized the use of AI to shape students' ethical awareness of technology, especially in simulation-based experimental projects. In their study, students were asked to create a scientific report using data obtained from an AI simulator, but the system also recorded acts of digital plagiarism or data manipulation (Laupichler et al., 2022; Stolpe & Hallström, 2024). This led to classroom discussions around AI ethics and responsible digital behavior.

In the context of digital collaboration skills, Kazanidis & Pellas (2024) explore how AI is used to form a group work ecosystem where students at the secondary education level work together to solve science problems using an AI assistant. The system observes individual contributions to the collaboration and provides automated feedback on the effectiveness of digital communication and scientific knowledge contribution (Kazanidis & Pellas, 2024).

Meanwhile, Chiu et al. (2024) explained that AI learning not only forms competence in using technology, but also opens students' understanding of how AI systems make decisions. This is important because one of the challenges in contemporary digital literacy is understanding that the information provided by digital systems (including search engines and chatbots) is not absolute truth, but is influenced by certain algorithms (Chiu et al., 2024). They emphasize the importance of introducing algorithmic awareness in the digital literacy curriculum of science.

Another element of digital literacy examined in these studies is the evaluation of digital media and scientific visualization. In research by Celik (2023), students in a chemistry class used an interactive molecular visualization-based AI system. The AI not only displayed molecular representations but also assessed students' understanding of the visual concepts through adaptive-based diagnostic questions

(Celik, 2023). This strengthened visual data interpretation skills, an essential part of modern scientific digital literacy.

Although most studies show positive impacts, some barriers are also identified, such as limited digital infrastructure in some developing countries, low teacher readiness in using AI pedagogically, and digital inequality among students. This is revealed in studies by Ayanwale et al. (2024) and Almasri (2024), which emphasize the importance of teacher training and adapting AI to local contexts. Overall, AI is used in these empirical studies as a facilitator of digital literacy through information evaluation, technology ethics, and collaborative work. As a mediator of science learning by adapting content and mapping students' digital abilities. And as an algorithmic mirror that shapes students' awareness of how AI works and how to use it critically (Almasri, 2024; Ayanwale et al., 2024).

RQ2 : What types and approaches of AI are most effective in shaping students' digital literacy competencies in science learning, based on empirical evidence?

Based on recent empirical studies in science education, digital platform-based approaches such as Solar System Scope, Virtual Laboratories, and Quizizz have shown significant effectiveness in supporting students' digital literacy through the use of smart technologies in the learning process (Yim & Su, 2025). Although not all of these platforms fully utilize artificial intelligence (AI) technology in the technical sense, most of them implement features based on adaptive algorithms, data-driven feedback, or multimodal interactions, which functionally integrate AI.

One of the platforms widely used in astronomy learning is Solar System Scope, an interactive 3D visual simulation that allows students to explore the solar system in real-time. Research by Zahara et al. (2020) shows that the use of Solar System Scope improves students' ability to evaluate visual information and integrate digital spatial data into their conceptual understanding. In the context of digital literacy, this experience encourages students to interact with complex digital interfaces, navigate planetarium data, and compare factual data from various sources. Thus, students not only understand science content but also develop digital literacy skills such as visual literacy, digital-based scientific information navigation, and digital data validation (Zahara et al., 2020).

Another platform that stands out in AI-based science learning is Virtual Laboratories. Platforms such as PhET Interactive Simulations, Labster, and Edmodo Virtual Lab provide digital experiments designed with interactive algorithms. In a study by Listiawati et al. (2022), the use of virtual labs in chemistry subjects helped students understand experimental procedures without having to face the risks of a physical laboratory. AI plays a role in adapting experimental scenarios based on user input, providing automatic alerts when errors occur, and suggesting improvements. These features are essential in developing digital safety awareness, data analysis literacy, and decision-making based on digital simulations. In addition, virtual labs provide an exploratory space that supports inquiry-based

learning and strengthening digital literacy competencies through direct feedback from the system (Listiawati et al., 2022).

Meanwhile, gamification-based educational approaches such as Quizizz also make unique contributions to shaping digital literacy. Although Quizizz is not entirely AI-based in its structure, the platform uses data to adapt the difficulty level of questions, record student performance statistics, and present analytical results that can be interpreted by students and teachers. Research by Situmorang et al. (2025) noted that the use of Quizizz in science learning not only increased learning motivation but also helped students read analytical reports of quiz results, recognize error patterns, and understand the meaning of “real-time feedback.” In this case, students develop digital data interpretation skills, metacognition-based reflection, and use of digital systems for self-assessment—all of which are part of the modern digital literacy framework (Situmorang et al., 2025).

Outside of these three platforms, there is also the integration of the use of Edpuzzle, an interactive video platform that allows teachers to insert questions, comments, and analytics into learning videos. Edpuzzle allows real-time tracking of student engagement and provides detailed reports on watch time, quiz responses, and student interaction breaks with the content. In a study by Kholid et al. (2024), the use of Edpuzzle in biology learning was proven effective in encouraging students to think critically about visual content, develop awareness of media sources, and optimize digital time management skills and scientific narrative understanding of science videos. Features such as fast-forward locking and time tracking are forms of algorithmic control that encourage students to take responsibility for their learning process, an important competency in the era of technology-based digital literacy (Kholid et al., 2024).

However, these approaches are only effective when combined with pedagogical strategies that encourage active and reflective engagement. A study by Yang et al. (2024) found that when teachers only used Quizizz or Edpuzzle as an assessment tool without reflective discussion, the impact on students' digital literacy tended to be minimal. In contrast, when the platforms were used in project-based or inquiry-based learning, there was a significant increase in literacy dimensions such as evaluating digital sources and understanding scientific logic structures (Yang et al., 2024).

In general, it can be concluded that the approach through platforms such as Solar System Scope, Virtual Laboratory, Quizizz, and Edpuzzle is very effective in shaping students' digital literacy if used consciously, integrated, and oriented towards the development of digital competence as a whole. Although these technologies do not always use AI in the narrow sense, features that are adaptive, data-driven, and enable multimodal interactions reflect the AI-enhanced education approach. Its effectiveness is largely determined by pedagogical integration and the extent to which students are involved in the reflective use of the technology they use.

4. Conclusion

This study aims to systematically examine how Artificial Intelligence (AI) is utilized in science learning to improve students' digital literacy, and to identify the most effective approaches based on empirical evidence. The research topic focuses on the correlation between AI-enhanced learning, digital literacy mastery, and science learning practices in the digital era.

From the results of the review of recent empirical studies, it was found that AI has been used to form various elements of digital literacy, such as the skills of evaluating digital information, understanding scientific visualization, being aware of technological ethics, and understanding the basics of how AI itself works. Platforms such as Solar System Scope, Virtual Laboratories, Quizizz, and Edpuzzle have been proven to support these skills through adaptive digital interactions, data-driven simulations, and real-time feedback that encourages reflection and independent learning. Thus, AI not only enriches the science learning experience but also contributes significantly to strengthening students' digital literacy.

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