



Systematic Literature Review: Digital Science Literacy in Science Education in the Era of Artificial Intelligence

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Abstract. The development of artificial intelligence (AI) in the 21st century has brought significant changes to the world of education, including in the learning of natural sciences (IPA). This study aims to analyze and describe the role of AI in the development of digital science literacy and identify the opportunities and challenges of its application in science learning. The study used a qualitative approach with the Systematic Literature Review (SLR) method based on Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). Data were obtained from the Scopus database and Google Scholar through the Publish or Perish application using the keywords "digital scientific literacy," "science education," and "AI." Based on the selection process, 15 articles were obtained that met the inclusion criteria between 2020 and 2026. The results indicate that AI plays a role in improving learning personalization, interactivity, access to scientific information, and the development of critical thinking and scientific communication skills in students. However, the implementation of AI also faces various challenges, such as information validity, algorithm bias, ethical issues, data security, and technological dependence. Digital science literacy in the AI era is developing into a multidimensional competency that integrates science literacy, digital literacy, and AI literacy. The novelty of this research lies in the integration of these three aspects into a single study focused on science learning. Therefore, we must approach the development of digital science literacy holistically to enable students to utilize AI technology critically, ethically, and responsibly.

Keywords: AI Literacy; Digital Scientific Literacy; Intelligence; Science Learning; Systematic Literature Review.

1. BACKGROUND

The development of digital technologies in the 21st century has profoundly transformed many aspects of human life, including education. Artificial intelligence (AI) is a rapidly growing technological innovation (Chen et al., 2020; Sajja et al., 2023). Its existence has not only changed how we obtain and process information, but also how we learn, teach, and build knowledge (Chen et al., 2020; Kamalov et al., 2023). In the field of education, AI is now used for various purposes: personalized learning, automated feedback, development of interactive learning resources, analysis of learning data, and the provision of virtual assistants to facilitate content comprehension (S. S. Lee & Moore, 2024; Tapalova & Zhiyenbayeva, 2022). These developments demonstrate the immense potential of AI to improve the quality of learning, making it more efficient, effective, and responsive to students' needs through adaptive recommendations of learning activities and real-time feedback. Access to learning is also crucial (Kamalov et al., 2023; Sajja et al., 2023).

In the context of science education, the use of artificial intelligence (AI) offers numerous opportunities for more relevant learning (Mahmud & Diyana, 2025; Utami, 2025). Fundamentally, science education aims not only to develop mastery of scientific concepts,

principles, and theories, but also to cultivate students' ability to think critically, solve problems, conduct scientific investigations, and make decisions based on reliable evidence (Kunnath & Botes, 2025; Mahmud & Diyana, 2025). AI can help students understand complex natural phenomena through digital simulations, visualization of abstract concepts, virtual laboratories, and access to a wider range of scientific resources (Mahmud & Diyana, 2025; Utami, 2025). Thus, the use of AI in science education has the potential to create more interactive, contextualized, and student-centered learning experiences. Parallel to these developments, the demands for 21st-century skills are also evolving. The goal is for students to master digital and information literacy skills to fully participate in a knowledge society (Fernández-Otoya et al., 2024; Pesha, 2022). Students should not only understand scientific concepts but also be able to access, analyze, evaluate, and utilize available information through various digital media (Martínez et al., 2022; Pesha, 2022). This skill is called scientific literacy, which has evolved into digital scientific literacy. Digital scientific literacy is the ability of an individual to understand scientific information, assess the accuracy and reliability of sources, interpret scientific information, and communicate scientific knowledge effectively and responsibly using digital technologies (Govender, 2025; Holincheck et al., 2022). In the era of digital transformation, digital scientific literacy is one of the essential skills to be developed through science education, as it plays a crucial role in training students capable of adapting to scientific and technological developments (Govender, 2025; Holincheck et al., 2022).

However, the development of artificial intelligence (AI) also presents numerous challenges that should not be overlooked. Generative AI technologies, such as ChatGPT and some large-scale language models (LLMs), enable rapid information generation and provide answers to a wide range of questions. However, AI-generated information is not always accurate, unbiased, or consistent with users' scientific knowledge (Nwoyibe, 2025; Rusandi et al., 2023). Some of this information may also contain errors, misinterpretations, or misinformation, which can impact students' understanding of scientific concepts. Furthermore, the widespread availability of AI poses risks such as technology dependency, weakening critical thinking skills, and discouraging students from verifying information sources. This poses significant challenges for science learning, as the process requires empirical evidence, logical reasoning, and critical evaluation of information (Holincheck et al., 2022; Laius & Orgusaar, 2025). These problems are exacerbated by students' daily exposure to an ever-increasing amount of digital information. It is often difficult to distinguish reliable scientific information from misinformation circulating online, on social media, and on AI platforms (Kresin et al., 2024; Pimentel, 2025). Furthermore, not all students possess the skills necessary

to assess the reliability of information sources, identify bias, or evaluate the quality of scientific evidence used (Kresin et al., 2024; Pimentel, 2025). Teachers, as facilitators of learning, also face the challenge of effectively and responsibly integrating AI technologies into their teaching (Daher, 2025; Ren & Wu, 2025). Therefore, developing digital literacy in science is becoming increasingly important. This will enable students to use technology intelligently while maintaining their scientific thinking in the face of the diversity of information available in the digital environment.

Furthermore, in line with the growing interest in the use of artificial intelligence in education, research on digital scientific literacy in science teaching continues to grow. Several studies have discussed the concepts of scientific literacy, digital literacy, AI literacy, and the use of AI in learning (Stolpe & Hallström, 2024; Yim & Su, 2025). However, these studies are usually conducted separately and focus on specific topics. Consequently, the relationship between the development of artificial intelligence (AI) in science teaching and digital scientific literacy remains incomplete. Yet, integrating understandings of scientific literacy, digital literacy, and AI technology is crucial to addressing the challenges facing education in the AI era.

In this context, research is needed that provides a comprehensive overview of the development of digital scientific literacy in science education in the AI era. Such research is crucial for understanding how AI technology contributes to the development of digital scientific literacy, the opportunities it offers for teaching, and the challenges teachers and students should anticipate. Therefore, the purpose of this study is to analyze and explain the role of artificial intelligence (AI) in the development of digital scientific literacy, as well as to identify the opportunities and challenges associated with its integration into learning in the AI era. The uniqueness of this research lies in its attempt to integrate the concepts of scientific culture, digital culture, and AI into one study focused on scientific learning, thus providing a more comprehensive perspective on the evolution of student literacy in the AI era.

2. METHOD

This study used a qualitative systematic literature review approach with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) method. PRISMA is a systematic and structured guideline for reporting various important stages in a Systematic Literature Review (SLR) so that each review process can be carried out transparently, clearly, and responsibly. The application of PRISMA helps improve the quality and credibility of research results because all procedures for selecting and analyzing literature are carried out

systematically (Cronin et al., 2008; Page et al., 2020). The process of searching for articles and references in this study focused on empirical research, both qualitative and quantitative research, which includes the main components of research such as abstracts, introductions, methods, results, and discussions. The search for research articles was conducted using Publish or Perish, using Scopus and Google Scholar as data sources. The article search process was carried out through several research databases using keywords that are appropriate to the research topic, namely "digital scientific literacy," "science education," and "AI." The search focused on empirical and conceptual research articles discussing digital science literacy, science learning, artificial intelligence, AI literacy, and the use of digital technology in science education. The obtained articles were then selected based on established inclusion and exclusion criteria. Inclusion criteria were used to determine articles eligible for analysis in accordance with the research objectives, while exclusion criteria were used to eliminate articles irrelevant to the study's focus. The inclusion and exclusion criteria for this study are presented in Table 1.

Table 1. Inclusion and Exclusion Criteria.

Inclusion Criteria	Exclusion Criteria
Articles discussing scientific literacy, science learning, Artificial Intelligence (AI), or AI Literacy	Articles not related to scientific literacy, science learning, or Artificial Intelligence
Research articles using qualitative, quantitative, experimental, or mixed methods	Non-research articles such as opinions, editorials, blogs, and news
Articles derived from primary sources	Duplicate articles or identical conference proceedings
Articles available in full text including abstract, introduction, methods, results, and discussion	Articles not available in full text
Articles published within the period 2020–2026	Articles published outside the 2020–2026 period
Articles indexed in Scopus or Google Scholar databases	Articles not indexed in the selected databases
Articles written in English	Articles written in languages other than English
Open-access articles that can be fully accessed	Articles that are not fully accessible (non-open access)

After the initial identification process, 143 articles were retrieved from the Scopus and Google Scholar databases. These articles were then screened based on thematic relevance, article availability, and whether they met the study's inclusion and exclusion criteria. Thirty-three articles were retrieved from the Scopus database, of which 11 were relevant and 22 were irrelevant. After a second screening based on article availability, eight articles met the eligibility criteria. Simultaneously, 110 articles were found in Google Scholar, of which 23 were relevant and 87 were irrelevant. After confirming their accessibility, seven articles met the criteria. Therefore, a total of 15 articles were analyzed in this study. The article selection process, based on the PRISMA methodology, is shown in Figure 1.

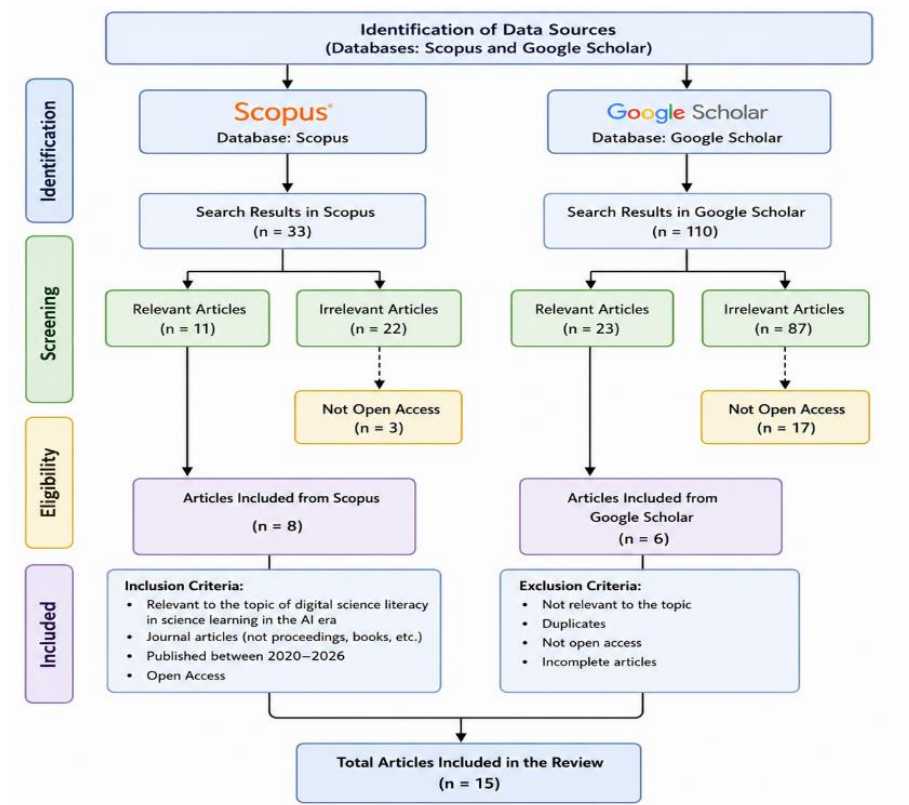


Figure 1. Article Selection Process Flowchart.

3. RESULT

The PRISMA selection process identified 15 articles that met the criteria for scientific research and were relevant to academia in the era of artificial intelligence. These articles, published between 2020 and 2026, covered a wide range of subjects related to AI in education, AI culture, technology-based learning, and 21st-century science culture. The analysis revealed that the studies covered topics such as the use of AI in education, faculty skill development, critical thinking, and preparing teachers to integrate AI into science education. The extraction results of the reviewed articles are shown in Table 2.

Table 2. Article Analysis Results.

No	Author(s) & Year	Article Title	Main Findings	Relevance to Digital Scientific Literacy in Science Learning
1	(Widodo et al., 2020)	The Effectiveness of Gadget-Based Interactive Multimedia in Improving Generation Z's Scientific Literacy	Interactive multimedia significantly improves students' scientific literacy.	Digital technology is effective for science learning.
2	Tapalova & Zhiyenbayeva (2022)	Artificial Intelligence in Education: AIED for Personalised Learning Pathways	AIED supports adaptive learning and the development of digital competencies.	Strengthens digital scientific literacy through AI-based technology use.

3	Park et al. (2023)	Integrating artificial intelligence into science lessons: teachers' experiences and views	AI and science complement each other, but are constrained by teachers' competence and readiness.	Digital literacy needs to be developed among teachers and students.
4	Chiu (2024)	The impact of Generative AI (GenAI) on practices, policies and research direction in education: a case of ChatGPT and Midjourney	GenAI enhances learning personalization and interactivity but raises ethical issues and concerns about information validity.	Supports AI-based information evaluation and critical thinking in science learning.
5	Karataş & Yüce (2024)	AI and the Future of Teaching: Preservice Teachers' Reflections on the Use of Artificial Intelligence in Open and Distributed Learning	AI improves the effectiveness of digital learning but raises ethical concerns and technology dependency.	Highlights the importance of AI literacy and teacher readiness in science education.
6	Ng et al. (2024)	Design and validation of the AI literacy questionnaire: The affective, behavioural, cognitive and ethical approach	AI literacy includes affective, behavioral, cognitive, and ethical dimensions.	Provides an AI literacy framework for science learning.
7	Stolpe & Hallström (2024)	Artificial Intelligence Literacy for Technology Education	Develops an AI literacy framework including AI knowledge, technical skills, and ethical/social understanding.	Enhances digital scientific literacy through AI understanding, critical thinking, systems thinking, and digital technology use.
8	G. G. Lee & Zhai (2024)	Using ChatGPT for Science Learning : A Study on Pre-service Teachers' Lesson Planning	ChatGPT supports inquiry, independent learning, and assessment but risks over-reliance.	Encourages digital scientific literacy through AI interaction and critical thinking.
9	Osborne & Allchin (2025)	Science literacy in the twenty-first century: informed trust and the competent outsider	Scientific literacy emphasizes the ability to evaluate the credibility of scientific information.	Serves as a theoretical foundation for digital scientific literacy and critical thinking.
10	Oh & Lee (2025)	Confronting Imminent Challenges in Humane Epistemic Agency in Science Education	AI-generated knowledge is automatic, but human knowledge remains superior in contextual and ethical aspects.	Emphasizes AI information evaluation and epistemological aspects.
11	Válek et al. (2025)	The use of generative AI in STEM education to develop scientific literacy and critical thinking	Generative AI supports the design of critical thinking-based learning tasks.	AI supports creativity and problem-solving in science learning.
12	Laius & Orgusaar (2025)	The Critical Role of Science Teachers' Readiness in Harnessing Digital Technology Benefits	Teachers use digital tools but still face limitations in digital competence.	Highlights the importance of science teachers' digital competence.
13	Huwer et al. (2025)	Competencies for teaching with and about artificial intelligence in the natural sciences - DiKoLAN AI	The DiKoLAN AI framework includes didactic, technological, and	Supports the development of AI competencies in science learning.

			socio-cultural competencies.		
14	Jantassova et al. (2026)	AI-Enhanced Digital STEM Language Learning in Technical Education	AI improves scientific communication and STEM literacy.	AI supports technology-based science learning.	
15	Janiūnienė et al. (2026)	How Social Science Academics Use AI – Activities and Tools	AI increases productivity but raises ethical and information quality concerns.	Digital scientific literacy includes information evaluation and AI ethics.	

Overall, the results of this study indicate that advances in artificial intelligence (AI) have a positive impact on science education. AI can facilitate personalized learning, facilitate access to scientific information, help visualize abstract concepts, and develop students' critical thinking skills. Furthermore, teachers have the opportunity to create interactive and adaptive learning experiences tailored to students' needs. However, several studies also highlight challenges associated with introducing AI into science education. These challenges include the validity of AI-generated information, algorithmic bias, data security, academic integrity, and technology dependency. Therefore, developing digital science literacy is crucial to enable students and teachers to use AI critically, ethically, and responsibly. In addition to analyzing the research findings, the reviewed articles were mapped based on the research methodology used, as shown in Table 3. This mapping aims to identify trends in research methods for a digital science culture in science education in the era of artificial intelligence.

Table 3. Mapping of Research Method Groups.

No	Research Method Group	Articles	Total
1	Qualitative Research	Park et al. (2023); G. G. Lee & Zhai (2024); Chiu (2024); Karataş & Yüce (2024); Oh & Lee (2025); Laius & Orgusaar (2025); Janiūnienė et al. (2026)	7
2	Conceptual / Review Studies	Tapalova & Zhiyenbayeva (2022); Stolpe & Hallström (2024); Osborne & Allchin (2025); Válek et al. (2025)	4
3	Experimental and Learning Implementation	Widodo et al. (2020); Jantassova et al. (2026)	2
4	Instrument and Framework Development	Ng et al. (2024); Huwer et al. (2025)	2

According to Table 3, the most frequently used research method in the analyzed articles was qualitative research, represented by seven articles. Qualitative research was used to explore opinions, experiences, and challenges related to the use of AI in education and the development of digital science literacy. Furthermore, four articles used a conceptual or observational approach to develop theoretical frameworks related to AI literacy, science literacy, and the use of digital technology in education. Two articles used experiential and action learning methods, primarily to test the effectiveness of AI-based instruction and interactive multimedia in improving students' digital science literacy. Meanwhile, two other studies focused on the

development of AI tools and competency frameworks to support the integration of AI into science education.

4. DISCUSSION

A systematic literature review indicates that the development of artificial intelligence (AI) has brought about a paradigm shift in the development of digital scientific knowledge in science education. However, a more detailed analysis reveals that the role of AI in this context is not linear but complex and multifaceted, encompassing pedagogical, epistemological, technological, and ethical aspects. An analysis of 15 papers reveals that AI is no longer simply a learning tool but a crucial component of 21st-century competencies needed by students and teachers.

In general, the literature clearly demonstrates that AI makes a positive contribution to the development of learning. Chiu (2024) suggests that innovative AI can transform teaching methods through personalization, enhanced interaction, and increased efficiency in assessment and educational management. This finding aligns with that of Tapalova & Zhiyenbayeva (2022), who highlight the role of artificial intelligence (AI) in education in creating adaptive learning pathways that meet students' needs. Jantassova et al. (2026) further develop this view, demonstrating that the integration of AI into STEM education not only enhances digital skills but also fosters intellectual development. Furthermore, it helps develop scientific communication skills and general scientific knowledge. A detailed comparison of these studies reveals significant differences in focus. Chiu (2024) focuses on macro-level changes in the education system, such as policy impacts and changes in teaching methods, while Tapalova & Zhiyenbayeva (2022) focus on micro-level aspects such as individual learning experiences. Jantassova et al. (2026) adopt an interdisciplinary approach to STEM education, demonstrating that the use of AI not only enhances learning effectiveness but also fosters the overall development of 21st-century skills. These differences indicate that there is currently no clear conclusion regarding the most effective model for integrating AI into science education.

Furthermore, several studies have shown that integrating AI into education presents various structural and cognitive challenges. Karataş & Yüce (2024) highlight the risks of technology dependency and data security issues associated with the use of AI in digital learning. These findings are corroborated by Janiūnienė et al. (2026), who state that while the use of AI in academic contexts can increase productivity, it also raises questions about academic integrity and data quality. Furthermore, Oh & Lee (2025) offer a more in-depth epistemological critique, arguing that AI, as an epistemological tool, is limited by a lack of

human context, values, and experience. In comparison, these three studies share the same perspective on AI as a neutral technology with philosophical implications for the learning process. This is particularly important in the context of science education, as science is not limited to facts and concepts but also involves processes of reasoning, knowledge verification, and meaning construction. Therefore, the use of AI without adequate digital science skills can lead to misunderstandings and shallow understanding.

In the context of scientific literacy, Osborne & Allchin (2025) made a crucial theoretical contribution through the concept of the competent outsider, an individual capable of evaluating the credibility of scientific information without being an expert in the field. This concept is increasingly important in the era of artificial intelligence (AI), as scientific information is now generated not only by humans but also by ethically oriented systems. Compared with the AI scientific literacy framework developed by Ng et al. (2024), there are clear similarities regarding information evaluation, ethical awareness, and reflective capacity. However, these two approaches continue to develop separately: scientific literacy focuses more on cognitive aspects, while AI literacy emphasizes understanding technology and its impacts. This lack of integration between scientific literacy and AI literacy represents a conceptual gap in existing research. Most studies only address these two concepts partially, without developing an integrated framework that explicitly connects them to science learning environments. However, in practice, learners are faced with situations where they must understand scientific concepts while evaluating information generated by AI. Therefore, to improve scientific literacy in the field of digital technology, a holistic approach is needed that integrates scientific, digital, and AI aspects.

Furthermore, practical research shows that the use of digital technology and artificial intelligence (AI) can enhance students' learning motivation. Widodo et al. (2020) demonstrated that interactive multimedia applications significantly enhance scientific knowledge through social science approaches and problem-solving. G. G. Lee & Zhai (2024) demonstrated that while creative AI applications such as ChatGPT can support inquiry based learning, self-directed learning, and performance assessment, they are imperfect and susceptible to technology dependency. These results confirm that interacting with AI can foster the development of digital science knowledge, but critical thinking is still necessary to evaluate the information received. A comparison of these studies shows that while AI technology has significant potential to enhance science learning, its application remains diverse and inconsistent. Some studies focus on technology-based approaches, while others prioritize instructional or curriculum aspects. This suggests that integrating AI into science education

requires the development of more systematic and empirically based models. Furthermore, a methodological analysis revealed that most studies still emphasize qualitative and conceptual approaches, while experimental research on the direct effectiveness of AI in enhancing digital science knowledge remains limited, highlighting the gap between conceptual development and practical application. In other words, while AI's potential in education is widely recognized, its application remains inadequate. However, there is still relatively little credible empirical evidence regarding the effectiveness of AI in scientific studies.

This study reveals that digital science literacy in the era of artificial intelligence (AI) is a complex and multifaceted concept. This literacy encompasses not only the ability to understand scientific concepts and utilize digital technology, but also critical thinking skills, information evaluation skills, ethical awareness, and an understanding of how AI works and its impacts. Therefore, a comprehensive and objective approach is needed to foster digital science literacy in science education. The primary objective of this study is to integrate previous research findings into a more comprehensive framework. This study demonstrates that AI is not merely a learning tool, but a key factor in developing 21st-century scientific skills. Furthermore, this study emphasizes the urgent need to develop AI-based learning models that aim to enhance students' epistemological, critical, and ethical skills, beyond simply using technology. Therefore, this study emphasizes that fostering digital science literacy in science education in the era of artificial intelligence must focus not only on technology but also on educating students to understand, evaluate, and think critically and responsibly about scientific information.

5. CONCLUSION

Based on a systematic literature review of 15 studies, this research concludes that artificial intelligence (AI) plays a crucial role in promoting digital science literacy in science education. AI supports personalized learning, improves access to scientific information, and develops students' critical thinking, science communication, and problem-solving skills. The use of AI offers numerous opportunities, including personalized learning, enhanced interactions, and increased access to scientific information. However, its implementation also presents challenges such as data accuracy, algorithm bias, ethical issues, and trust in technology. Therefore, developing digital science literacy through AI requires a holistic approach that enables students and teachers to use technology critically, adaptively, and responsibly in the field of AI science. This research suggests that developing digital science literacy in science education should emphasize a holistic and integrated approach that combines pedagogy,

technology, and epistemology. Furthermore, additional empirical and experimental research is needed to examine the direct impact of AI adoption on students' digital science literacy.

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