

From digital literacy to AI literacy: A bibliometric review in elementary education contexts

Umar¹✉, Sri Suryaningsih², Nurwalidainismawati³, Irma Sofiasyari⁴

¹²³STKIP Harapan Bima, Indonesia

⁴Universitas Pamulang, Indonesia

¹Email: umar09@gmail.com

²Email: srisuryaningsih@habi.ac.id

³Email: nurwalidainismawati@habi.ac.id

⁴Email: dosen03276@unpam.ac.id



(✉ Corresponding Author)

Abstract

The rapid development of Artificial Intelligence (AI) has increased the importance of AI literacy in elementary education contexts. This study aims to analyze the development and research trends of AI literacy in elementary education through a bibliometric perspective. The data were retrieved from Google Scholar using Publish or Perish, covering publications from 2020 to 2026. From the initial dataset of 500 documents, relevant publications were analyzed using Microsoft Excel and VOSviewer. The findings revealed a substantial increase in publication trends, particularly after 2023, with the highest number of publications identified in 2025. Citation analysis indicated that highly cited studies were dominated by themes related to AI literacy frameworks, generative AI, AI ethics, teacher readiness, and AI-supported learning environments. Furthermore, the co-occurrence, overlay, and density visualizations demonstrated that recent research increasingly emphasizes topics such as ChatGPT, generative AI, digital literacy, and AI literacy education in elementary school contexts. Overall, the findings indicate that AI literacy research has evolved from general digital literacy toward more AI-oriented educational approaches and future-ready learning environments in elementary education.

Keywords: AI literacy, artificial intelligence, elementary education, digital literacy, generative AI

Citation | Umar, U., Suryaningsih, S., Nurwalidainismawati, N., & Sofiasyari, I. (2026). From digital literacy to AI literacy: A bibliometric review in elementary education contexts. *Journal of Language and Literacy Learning*, 2(1), 51–64.

Received: June 19, 2026 | **Revised:** June 16, 2026 | **Accepted:** June 20, 2026 | **Published:** June 30, 2026

Contribution to Literature: This study provides a bibliometric overview of AI literacy research in elementary education, highlighting the shift from digital literacy toward AI-oriented learning environments. It also identifies emerging themes, dominant research trends, and future directions related to generative AI and AI literacy education in primary school contexts.

1. Introduction

The rapid expansion of digital technologies has transformed literacy practices in contemporary education, particularly in elementary school contexts where students increasingly interact with multimodal and technology-mediated learning environments. Literacy is no longer limited to reading and writing printed texts but has evolved into broader digital, visual, and multimodal meaning-making practices that require students to critically engage with information, media, and communication technologies. Within this transformation, digital literacy has become a fundamental competency for navigating educational, social, and technological environments in the twenty-first century. Recent educational research further emphasizes that literacy development in contemporary classrooms should integrate critical, sociocultural, and technological dimensions to prepare students for increasingly complex digital societies (Nasir et al., 2021; Sawyer, 2022; Yang, 2022). In elementary education, this shift is particularly significant because young learners are now exposed to algorithm-driven platforms, recommendation systems, and AI-mediated communication from an early age (Long & Magerko, 2020; Moon et al., 2024).

The emergence of Artificial Intelligence (AI) technologies has further accelerated the transformation of literacy practices in education. AI is increasingly embedded in everyday digital experiences through virtual assistants, content recommendation systems, generative AI applications, and automated communication platforms, thereby reshaping how individuals access, interpret, and construct information (Epstein et al., 2023; Gong et al., 2023). Consequently, traditional digital literacy frameworks are no longer sufficient to address the growing complexity of AI-mediated environments. Educational scholars have increasingly argued that AI literacy should be viewed as an extension of digital literacy that encompasses not only technical understanding but also ethical awareness, critical evaluation, and responsible participation in AI-driven societies (Long & Magerko, 2020; Yim & Su, 2025). This shift becomes particularly important in elementary education contexts because children interact with AI systems long before they fully understand how algorithmic processes shape digital content and online experiences (Ottenbreit-Leftwich et al., 2022; Touretzky et al., 2019).

Recent studies on AI literacy in elementary and primary education have primarily focused on introducing basic AI concepts, computational thinking, machine learning activities, and AI-supported classroom practices (Ottenbreit-Leftwich et al., 2022; Wu et al., 2024). Several studies have also highlighted the importance of ethical AI education, including issues related to fairness, bias, misinformation, privacy, and responsible technology use among young learners (Ma et al., 2025; Yim, 2024). Furthermore, emerging frameworks such as the Associative Model of AI Literacy (AMAIL) demonstrate that AI literacy in elementary education should integrate interaction with AI, conceptual understanding, evaluation, and ethical reflection through meaningful and contextual learning experiences (Relmasira et al., 2023). These developments indicate that AI literacy is increasingly positioned within broader multiliteracy and critical literacy perspectives rather than merely as technical competence.

Although studies related to AI literacy continue to grow rapidly, the research landscape remains fragmented across different educational perspectives, technological focuses, and pedagogical approaches. Existing studies tend to emphasize empirical classroom implementation, AI learning tools, computational thinking integration, or

conceptual AI literacy frameworks (Almatrafi et al., 2024; Chung et al., 2025). However, limited attention has been given to systematically mapping how AI literacy research in elementary education has evolved from broader digital literacy discourses toward critical, ethical, and multiliteracy-oriented perspectives. In particular, there remains a lack of bibliometric studies that comprehensively examine publication trends, conceptual structures, thematic evolution, and emerging research directions related to AI literacy within elementary education contexts.

Therefore, this study aims to map the development of AI literacy research in elementary education through a bibliometric review approach. Specifically, this study investigates publication trends, influential themes, conceptual structures, and emerging directions in AI literacy research while examining the evolving transition from digital literacy toward AI literacy in elementary education contexts. By positioning AI literacy within broader multiliteracy and digital meaning-making practices, this study contributes to current discussions on literacy transformation, educational technology, and elementary literacy education in the era of artificial intelligence.

2. Literature Review

The growing integration of artificial intelligence into educational environments has significantly transformed contemporary literacy practices, particularly within elementary education contexts. AI technologies are increasingly embedded in students' daily experiences through recommendation systems, generative AI applications, virtual assistants, and algorithm-driven digital platforms, thereby reshaping how learners access, interpret, and construct meaning in digital environments (Epstein et al., 2023; Long & Magerko, 2020). Consequently, literacy is no longer viewed solely as the ability to read and write conventional texts but has evolved toward broader multimodal, digital, and AI-mediated meaning-making practices that require critical, ethical, and technological competencies (Nasir et al., 2021; Sawyer, 2022). Within this transformation, AI literacy has emerged as an important extension of digital literacy in contemporary education.

Recent scholarship conceptualizes AI literacy as a multidimensional competence involving technical understanding, critical evaluation, ethical awareness, and responsible engagement with AI systems (Long & Magerko, 2020). In elementary education, AI literacy is increasingly associated with the development of students' abilities to recognize AI technologies, understand algorithmic processes, evaluate AI-generated content, and critically reflect on the social implications of AI use (Touretzky et al., 2019; Yim & Su, 2025). Several educational frameworks further emphasize that AI literacy should be integrated with constructivist, multiliteracy, and sociocultural learning perspectives to ensure that students develop meaningful and contextual understanding rather than merely technical skills (Relmasira et al., 2023).

The increasing attention toward AI literacy has also encouraged the emergence of various empirical and conceptual studies in elementary and primary education. Previous studies have explored AI literacy from multiple perspectives, including AI curriculum development, computational thinking integration, AI ethics education, teacher readiness, and multimodal AI-supported learning environments (Ma et al., 2025; Ottenbreit-Leftwich et al., 2022; Wu et al., 2024). Moreover, recent systematic reviews indicate that AI literacy research is expanding rapidly across educational disciplines and continues to evolve alongside the emergence of generative AI technologies (Almatrafi et al., 2024; Liu & Zhong, 2024). However, despite this rapid growth, the literature remains fragmented, particularly regarding how AI literacy research in elementary education has evolved conceptually from digital literacy toward critical and multiliteracy-oriented perspectives.

As summarized in Table 1, recent studies have primarily focused on conceptual frameworks, AI literacy implementation, ethical AI education, and systematic reviews of AI learning practices. Nevertheless, limited studies have attempted to map the broader intellectual structure, thematic evolution, and research trends of AI literacy in elementary education through bibliometric approaches. Therefore, this study seeks to address this gap by providing a bibliometric review of AI literacy research in elementary education contexts.

Table 1. Research on AI literacy in elementary education contexts.

No	Title	Reference
1	A systematic review of AI literacy conceptualization, constructs, and implementation and assessment efforts (2019–2023)	Almatrafi et al. (2024)
2	A systematic review on how educators teach AI in K-12 education	Liu & Zhong (2024)
3	Developing an AI literacy diagnostic tool for elementary school students	Chung et al. (2025)
4	Artificial intelligence literacy education in primary schools: A review	Yim & Su (2025)

3. Research Method

3.1. Research Design

This study employed a bibliometric review design to systematically map and analyze the development of AI literacy research in elementary education contexts. Bibliometric analysis was selected because it enables researchers to identify publication trends, influential studies, thematic developments, conceptual structures, and emerging research directions within a specific field of study through quantitative mapping techniques. In this study, bibliometric analysis was used to examine the evolution of AI literacy research from digital literacy perspectives toward broader AI-mediated and multiliteracy-oriented educational discussions in elementary education contexts.

3.2. Data Sources

The data used in this study were obtained from Google Scholar through the Publish or Perish application. Google Scholar was selected because it provides broad multidisciplinary coverage and captures diverse educational publications related to AI literacy, digital literacy, and elementary education. The publication years were limited to 2020–2026 to capture recent developments in AI literacy research, particularly following the rapid growth of generative AI technologies in educational contexts. The search process was conducted using several keywords and phrases, including “AI literacy”, “artificial intelligence literacy”, “digital literacy”, “elementary education”, “primary education”, “elementary school”, and “AI in education”. These keywords were combined during the retrieval process to obtain relevant publications aligned with the focus of this study. The search yielded 500 publications relevant to AI literacy and elementary education topics. The retrieved data were exported in RIS and CSV formats to support bibliometric processing, filtering, and visualization analysis.

3.3. Procedure of Data Collection

The data collection procedure was conducted through several stages. First, relevant keywords related to AI literacy, digital literacy, artificial intelligence in education, and elementary education were identified and combined during the search process in Publish or Perish. Second, the retrieved publications were screened to ensure their relevance to educational and literacy-related contexts. Third, duplicate, irrelevant, and incomplete

records were excluded from the dataset. Fourth, the final dataset was exported in RIS format for bibliometric mapping in VOSviewer and CSV format for descriptive analysis using Microsoft Excel. The selected publications were then organized based on publication year, citation frequency, keywords, authorship, and source information to facilitate further analysis.

3.4.Data Analysis

The data analysis was conducted using Microsoft Excel and VOSviewer. Microsoft Excel was used to organize and analyze descriptive data, including publication trends, citation frequencies, source distribution, and author productivity. Meanwhile, VOSviewer was employed to visualize bibliometric networks and thematic relationships through co-occurrence, co-authorship, and keyword mapping analyses. The visualization results were used to identify dominant themes, research clusters, conceptual relationships, and emerging trends in AI literacy research within elementary education contexts. In addition, the twenty most-cited articles were identified and presented in the findings section to highlight influential studies contributing to the development of AI literacy research.

4. Results and Discussion

4.1.AI Literacy in Elementary Education Contexts 2020–2026

The analysis of publication output from 2020 to 2026 reveals a substantial increase in research related to AI literacy in elementary education contexts. The data were retrieved from Google Scholar through Publish or Perish using keywords associated with AI literacy, Artificial Intelligence, elementary education, and primary school learning environments. From the initial dataset of 500 retrieved documents, the publications were screened and organized for bibliometric analysis based on relevance, keywords, publication type, and research focus.

As presented in Table 2 and visualized in Figure 1, the annual publication trend demonstrates a gradual increase between 2020 and 2022, followed by a significant rise beginning in 2023. The number of publications increased from 35 documents in 2023 to 97 documents in 2024 and reached its highest point with 263 publications in 2025. Although the number of publications in 2026 appears lower, this condition is likely influenced by the ongoing indexing and publication process for the current year. Overall, these findings indicate that AI literacy has become an emerging and rapidly growing research topic in elementary education contexts.

The increasing publication trend also reflects the growing global concern regarding the importance of introducing Artificial Intelligence concepts, digital literacy, and computational thinking skills at the elementary education level. Earlier studies mainly focused on digital literacy and technology integration in primary education, while recent publications increasingly discuss AI literacy frameworks, ethical AI awareness, AI-based learning activities, and AI-supported instructional practices for young learners. This finding indicates a significant shift from general digital competence toward more AI-oriented educational approaches and future-ready learning environments. Similar trends were also identified in previous studies emphasizing that AI literacy has become an essential competency in contemporary education, particularly in preparing students to interact critically and responsibly with emerging technologies (Long & Magerko, 2020).

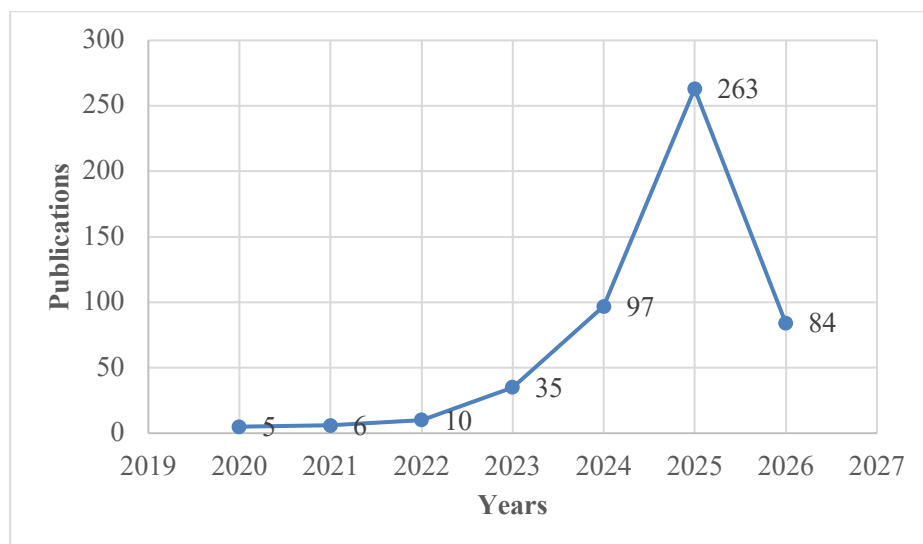


Figure 1. Annual report of publications.

Table 2. Annual report research on “AI literacy in elementary education contexts”.

Years	Publications	(%) of Publications
2020	5	1%
2021	6	1%
2022	10	2%
2023	35	7%
2024	97	19%
2025	263	53%
2026	84	17%
Total	500	100%

4.2. Most Influential and Highly Cited Publications

The citation analysis identifies the most influential publications contributing to the development of AI literacy in elementary education contexts. As presented in Table 3, the most highly cited studies are predominantly related to AI literacy frameworks, generative Artificial Intelligence, AI ethics, AI-supported learning tools, and teachers’ perceptions toward AI integration in educational environments. The most highly cited publication is Embracing the future of Artificial Intelligence in the classroom: the relevance of AI literacy, prompt engineering, and critical thinking in modern education by [Walter \(2024\)](#) with 1625 citations, followed by AI literacy in K-12: a systematic literature review with 998 citations. These findings indicate the growing scholarly interest in preparing students and educators for AI-integrated learning environments.

The citation trend also demonstrates that recent research increasingly emphasizes AI literacy not only as technological competence but also as a combination of critical thinking, ethical awareness, computational understanding, and responsible AI use in educational settings. Several highly cited studies focus on AI ethics curricula, generative AI in education, AI chatbot implementation, and teachers’ digital competence, indicating that AI literacy is becoming an interdisciplinary concept within elementary and K-12 education research. In addition, the dominance of studies published between 2023 and 2025 reflects the rapid expansion of generative AI technologies and their influence on educational practices worldwide.

Furthermore, many influential publications discuss the role of teachers and educational institutions in supporting AI literacy development among young learners.

This suggests that successful AI integration in elementary education depends not only on technological access but also on pedagogical readiness, ethical considerations, and instructional design. Similar findings were reported in previous studies emphasizing that AI literacy should include cognitive, ethical, and social dimensions to prepare students for future digital societies (Casal-Otero et al., 2023; Long & Magerko, 2020). These findings also reinforce the argument that AI literacy is emerging as an essential competency in contemporary elementary education contexts.

Table 3. Most cited articles on AI literacy in elementary education contexts.

No	Cites	Title	Year	Cites Per Year	Ref.
1	1625	Embracing the future of Artificial Intelligence in the classroom: the relevance of AI literacy, prompt engineering, and critical thinking in modern education	2024	812.50.00	Walter (2024)
2	998	AI literacy in K-12: a systematic literature review	2023	332.67	Casal-Otero et al. (2023)
3	724	Speculative futures on ChatGPT and generative artificial intelligence (AI): A collective reflection from the educational landscape	2023	241.33.00	Bozkurt et al. (2023)
4	719	Exploring teachers' perceptions of artificial intelligence as a tool to support their practice in Estonian K-12 education	2022	179.75	Chounta et al. (2022)
5	573	Integrating ethics and career futures with technical learning to promote AI literacy for middle school students: An exploratory study	2023	191.00.00	Zhang et al. (2023)
6	459	Artificial intelligence (AI) learning tools in K-12 education: A scoping review	2025	459.00.00	Yim & Su (2024)
7	446	Analysing the impact of artificial intelligence and computational sciences on student performance: Systematic review and meta-analysis	2023	148.67	García-Martínez et al. (2023)
8	380	Factors influencing university students' behavioral intention to use generative artificial intelligence: Integrating the theory of planned behavior and AI literacy	2025	380.00.00	Wang et al. (2025)
9	298	AI+ ethics curricula for middle school youth: Lessons learned from three project-based curricula	2023	99.33.00	Williams et al. (2023)
10	266	Machine learning and the five big ideas in AI	2023	88.67	Touretzky et al. (2023)
11	252	The mediating effects of needs satisfaction on the relationships between prior knowledge and self-regulated learning through artificial intelligence chatbot	2023	84.00.00	Xia et al. (2023)
12	250	Implementing artificial intelligence education for middle school technology education in Republic of Korea	2024	125.00.00	Park & Kwon (2024)

No	Cites	Title	Year	Cites Per Year	Ref.
13	240	Relationship between teachers' digital competence and attitudes towards artificial intelligence in education	2024	120.00.00	Galindo-Domínguez et al. (2024)
14	230	The current research trend of artificial intelligence in language learning: A systematic empirical literature review from an activity theory perspective	2022	57.50.00	Yang & Kyun, (2022)
15	226	Integrating artificial intelligence into science lessons: Teachers' experiences and views	2023	75.33.00	Park et al. (2023)
16	222	Benefits, challenges, and methods of artificial intelligence (AI) chatbots in education: A systematic literature review	2024	111.00.00	Gökçearsan et al. (2024)
17	216	Generative AI in education: Pedagogical, theoretical, and methodological perspectives	2024	108.00.00	Noroozi et al. (2024)
18	212	AI and Chat GPT in language teaching: Enhancing EFL classroom support and transforming assessment techniques	2023	70.67	Amin (2023)
19	197	Towards an AI-literate future: A systematic literature review exploring education, ethics, and applications	2025	197.00.00	Biagini (2025)

4.3. Visualization of Research Data Mapping of AI Literacy in Elementary Education Contexts

The co-occurrence analysis was conducted using VOSviewer to identify the conceptual structure and thematic relationships within AI literacy research in elementary education contexts. The minimum number of occurrences of a term was set at 10. Of the 2510 identified terms, 60 terms met the threshold requirement. Based on the relevance score generated by the software, 36 of the most relevant terms were selected for network visualization analysis. As illustrated in Figure 2, the co-occurrence network demonstrates a structured relationship among research themes and resulted in four major clusters consisting of 36 interconnected items.

The first cluster (red), consisting of 10 items, includes ai tool, artificial intelligence literacy, attitude, chatgpt, child, context, effect, impact, primary school, and systematic review. This cluster mainly focuses on the implementation of AI tools, children's perceptions, and the impact of AI literacy integration within primary school learning environments. The second cluster (green), comprising 9 items, includes ai literacy education, effectiveness, elementary education, elementary school, elementary school student, elementary schools, generative ai, implementation, and systematic literature review. This cluster emphasizes the effectiveness and implementation of AI literacy education in elementary school contexts, particularly related to generative AI integration and learning practices.

The third cluster (blue), with 9 items, includes ai education challenge, focus, importance, need, primary education, primary level, review, and utilization. This cluster reflects discussions regarding challenges, educational needs, and the importance of AI literacy development at the primary education level. Meanwhile, the fourth cluster (yellow), consisting of 8 items, includes age, ai technology, challenge, digital literacy, era, Indonesia, opportunity, and training. This cluster highlights the relationship between

Furthermore, the density visualization shown in Figure 4 highlights the most dominant and frequently discussed themes within the research field. Terms such as AI literacy, elementary education, generative AI, digital literacy, and primary school appear as the most densely connected areas, indicating their central role in current research developments. At the same time, newer themes such as ChatGPT, AI technology, and AI education challenge have emerged as important research directions, reflecting the growing attention toward the integration of Artificial Intelligence in elementary learning environments.

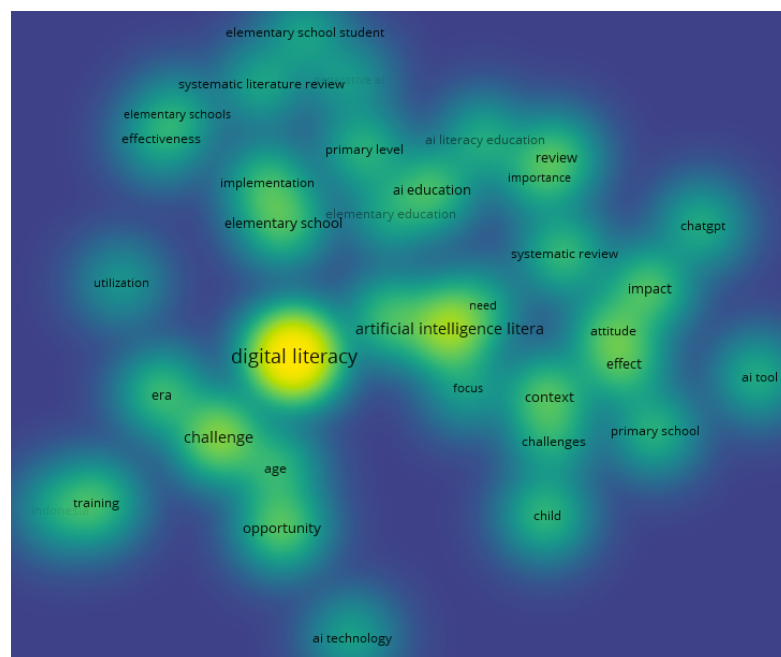


Figure 4. Density visualization based on the co-occurrence of terms.

4.4. Synthesis and Implications

The findings of this bibliometric study demonstrate that research on AI literacy in elementary education contexts has grown significantly between 2020 and 2026, particularly following the rapid emergence of generative Artificial Intelligence technologies. The increasing publication trends, citation patterns, and visualization mapping collectively indicate that AI literacy research has evolved from general digital literacy and technology integration toward more AI-oriented educational approaches. Recent studies increasingly emphasize themes such as generative AI, ChatGPT, AI literacy education, AI ethics, and teacher readiness, suggesting that AI literacy is becoming an important component of future-ready elementary education. Similar trends were also identified in previous studies highlighting the growing importance of AI literacy competencies in K-12 and primary education contexts (Casal-Otero et al., 2023; Long & Magerko, 2020).

These findings imply that elementary education institutions and educators need to prepare more adaptive learning environments that support the development of AI literacy from an early age. AI literacy should not only focus on technical understanding but also include ethical awareness, critical thinking, digital responsibility, and appropriate AI utilization in learning activities. Furthermore, future studies are encouraged to explore more empirical investigations regarding AI literacy implementation, teacher training, AI-supported instructional practices, and the integration of generative AI technologies in elementary education settings.

5. Conclusion

This bibliometric study demonstrates that research on AI literacy in elementary education contexts has experienced significant growth between 2020 and 2026, particularly following the rapid expansion of generative Artificial Intelligence technologies. The findings revealed that recent studies increasingly emphasize themes related to AI literacy education, generative AI, ChatGPT, digital literacy, AI ethics, and teacher readiness within elementary learning environments. In addition, the visualization mapping confirmed that AI literacy research is evolving from general technology integration toward more AI-oriented and future-ready educational approaches. These findings suggest that AI literacy has become an emerging and essential competency in elementary education, particularly in preparing young learners to interact critically, ethically, and responsibly with Artificial Intelligence technologies.

Conflict of Interest Statement

The authors declare that there is no conflict of interest regarding the publication of this article.

Funding Acknowledgment

This research received no external funding from any party.

Author Contributions

Umar: Conceptualization, initial draft writing, data collection; Suryaningsih: Methodology; Nurwalidainismawati: Final editing; Sofiasyari: Revision.

References

- Almatrafi, O., Johri, A., & Lee, H. (2024). A systematic review of AI literacy conceptualization, constructs, and implementation and assessment efforts (2019–2023). *Computers and Education Open*, 6, 100173. <https://doi.org/10.1016/j.caeo.2024.100173>
- Amin, M. Y. M. (2023). AI and Chat GPT in language teaching: Enhancing EFL classroom support and transforming assessment techniques. *International Journal of Higher Education Pedagogies*, 4(4), 1–15.
- Biagini, G. (2025). Towards an AI-literate future: A systematic literature review exploring education, ethics, and applications. *International Journal of Artificial Intelligence in Education*, 35(4), 2616–2666. <https://doi.org/10.1007/s40593-025-00466-w>
- Bozkurt, A., Xiao, J., Lambert, S., Pazurek, A., & Crompton, H. (2023). Speculative futures on ChatGPT and generative artificial intelligence (AI): A collective reflection from the educational landscape. *Asian Journal of Distance Education*, 18(1), 53–130.
- Casal-Otero, L., Catala, A., Fernández-Morante, C., Taboada, M., Cebreiro, B., & Barro, S. (2023). AI literacy in K-12: A systematic literature review. *International Journal of STEM Education*, 10(1), 29. <https://doi.org/10.1186/s40594-023-00418-7>
- Chounta, I.-A., Bardone, E., Raudsep, A., & Pedaste, M. (2022). Exploring teachers' perceptions of artificial intelligence as a tool to support their practice in Estonian K-12 education. *International Journal of Artificial Intelligence in Education*, 32(3), 725–755. <https://doi.org/10.1007/s40593-021-00243-5>

- Chung, K., Kim, S., Jang, Y., Choi, S., & Kim, H. (2025). Developing an AI literacy diagnostic tool for elementary school students. *Education and Information Technologies*, 30(1), 1013–1044. <https://doi.org/10.1007/s10639-024-13097-w>
- Epstein, Z., Hertzmann, A., the Investigators of Human Creativity, Akten, M., Farid, H., Fjeld, J., Frank, M. R., Groh, M., Herman, L., Leach, N., Mahari, R., Pentland, A. “Sandy,” Russakovsky, O., Schroeder, H., & Smith, A. (2023). Art and the science of generative AI. *Science*, 380(6650), 1110–1111. <https://doi.org/10.1126/science.adh4451>
- Galindo-Domínguez, H., Delgado, N., Campo, L., & Losada, D. (2024). Relationship between teachers’ digital competence and attitudes towards artificial intelligence in education. *International Journal of Educational Research*, 126, 102381. <https://doi.org/10.1016/j.ijer.2024.102381>
- García-Martínez, I., Fernández-Batanero, J. M., Fernández-Cerero, J., & León, S. P. (2023). Analysing the impact of artificial intelligence and computational sciences on student performance: Systematic review and meta-analysis. *Journal of New Approaches in Educational Research*, 12(1), 171–197. <https://doi.org/10.7821/naer.2023.1.1240>
- Gökçearslan, Ş., Tosun, C., & Erdemir, Z. G. (2024). Benefits, Challenges, and Methods of Artificial Intelligence (AI) Chatbots in Education: A Systematic Literature Review. *International Journal of Technology in Education*, 7(1), 19–39. <https://doi.org/10.46328/ijte.600>
- Gong, C., Jing, C., Chen, X., Pun, C. M., Huang, G., Saha, A., Nieuwoudt, M., Li, H.-X., Hu, Y., & Wang, S. (2023). Generative AI for brain image computing and brain network computing: A review. *Frontiers in Neuroscience*, 17, 1203104. <https://doi.org/10.3389/fnins.2023.1203104>
- Liu, X., & Zhong, B. (2024). A systematic review on how educators teach AI in K-12 education. *Educational Research Review*, 45, 100642. <https://doi.org/10.1016/j.edurev.2024.100642>
- Long, D., & Magerko, B. (2020). What is AI literacy? Competencies and design considerations. *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, 1–16. <https://doi.org/10.1145/3313831.3376727>
- Ma, M., Ng, D. T. K., Liu, Z., & Wong, G. K. W. (2025). Fostering responsible AI literacy: A systematic review of K-12 AI ethics education. *Computers and Education: Artificial Intelligence*, 8, 100422. <https://doi.org/10.1016/j.caeai.2025.100422>
- Moon, H., Go, H., Lee, Y., & Kim, S.-W. (2024). Investigating factors in artificial intelligence literacy for Korean elementary school students. *International Journal on Advanced Science, Engineering and Information Technology*, 14(4), 1226–1232. <https://doi.org/10.18517/ijaseit.14.4.16998>
- Nasir, N. S., Lee, C. D., Pea, R., & McKinney De Royston, M. (2021). Rethinking learning: What the interdisciplinary science tells us. *Educational Researcher*, 50(8), 557–565. <https://doi.org/10.3102/0013189X211047251>
- Noroozi, O., Soleimani, S., Farrokhnia, M., & Banihashem, S. K. (2024). Generative AI in education: Pedagogical, theoretical, and methodological perspectives. *International Journal of Technology in Education*, 7(3), 373–385. <https://doi.org/10.46328/ijte.845>
- Ottenbreit-Leftwich, A., Glazewski, K., Hmelo-Silver, C., Jantaraweragul, K., Jeon, M., Chakraborty, S., Scribner, A., Lee, S., Mott, B., & Lester, J. (2022). Is elementary AI education possible? *Proceedings of the 54th ACM Technical Symposium on*

- Computer Science Education* V. 2, 1364–1364.
<https://doi.org/10.1145/3545947.3576308>
- Park, J., Teo, T. W., Teo, A., Chang, J., Huang, J. S., & Koo, S. (2023). Integrating artificial intelligence into science lessons: Teachers' experiences and views. *International Journal of STEM Education*, 10(1), 61.
<https://doi.org/10.1186/s40594-023-00454-3>
- Park, W., & Kwon, H. (2024). Implementing artificial intelligence education for middle school technology education in Republic of Korea. *International Journal of Technology and Design Education*, 34(1), 109–135.
<https://doi.org/10.1007/s10798-023-09812-2>
- Relmasira, S. C., Lai, Y. C., & Donaldson, J. P. (2023). Fostering AI literacy in elementary science, technology, engineering, art, and mathematics (STEAM) education in the age of generative AI. *Sustainability*, 15(18), 13595.
<https://doi.org/10.3390/su151813595>
- Sawyer, R. K. (2022). An introduction to the learning sciences. In R. K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (3rd ed., pp. 1–24). Cambridge University Press. <https://doi.org/10.1017/9781108888295.002>
- 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(01), 9795–9799.
<https://doi.org/10.1609/aaai.v33i01.33019795>
- Touretzky, D., Gardner-McCune, C., & Seehorn, D. (2023). Machine learning and the five big ideas in AI. *International Journal of Artificial Intelligence in Education*, 33(2), 233–266. <https://doi.org/10.1007/s40593-022-00314-1>
- Walter, Y. (2024). Embracing the future of artificial intelligence in the classroom: The relevance of AI literacy, prompt engineering, and critical thinking in modern education. *International Journal of Educational Technology in Higher Education*, 21(1), 15. <https://doi.org/10.1186/s41239-024-00448-3>
- Wang, C., Wang, H., Li, Y., Dai, J., Gu, X., & Yu, T. (2025). Factors influencing university students' behavioral intention to use generative artificial intelligence: Integrating the theory of planned behavior and AI literacy. *International Journal of Human-Computer Interaction*, 41(11), 6649–6671.
<https://doi.org/10.1080/10447318.2024.2383033>
- Williams, R., Ali, S., Devasia, N., DiPaola, D., Hong, J., Kaputsos, S. P., Jordan, B., & Breazeal, C. (2023). AI+ ethics curricula for middle school youth: Lessons learned from three project-based curricula. *International Journal of Artificial Intelligence in Education*, 33(2), 325–383. <https://doi.org/10.1007/s40593-022-00298-y>
- Wu, D., Chen, M., Chen, X., & Liu, X. (2024). Analyzing K-12 AI education: A large language model study of classroom instruction on learning theories, pedagogy, tools, and AI literacy. *Computers and Education: Artificial Intelligence*, 7, 100295. <https://doi.org/10.1016/j.caeai.2024.100295>
- Xia, Q., Chiu, T. K. F., Chai, C. S., & Xie, K. (2023). The mediating effects of needs satisfaction on the relationships between prior knowledge and self-regulated learning through artificial intelligence chatbot. *British Journal of Educational Technology*, 54(4), 967–986. <https://doi.org/10.1111/bjet.13305>
- Yang, H., & Kyun, S. (2022). The current research trend of artificial intelligence in language learning: A systematic empirical literature review from an activity theory perspective. *Australasian Journal of Educational Technology*, 38(5), 180–210. <https://doi.org/10.14742/ajet.7492>

- 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>
- Yim, I. H. Y. (2024). Artificial intelligence literacy in primary education: An arts-based approach to overcoming age and gender barriers. *Computers and Education: Artificial Intelligence*, 7, 100321. <https://doi.org/10.1016/j.caeai.2024.100321>
- Yim, I. H. Y., & Su, J. (2024). Artificial intelligence (AI) learning tools in K-12 education: A scoping review. *Journal of Computers in Education*. <https://doi.org/10.1007/s40692-023-00304-9>
- Yim, I. H. Y., & Su, J. (2025). Artificial intelligence literacy education in primary schools: A review. *International Journal of Technology and Design Education*, 35(5), 2175–2204. <https://doi.org/10.1007/s10798-025-09979-w>
- 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>