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# Digital Literacy in STEM Education: A Bibliometric and Systematic Literature Network Analysis

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**Abstract:** The rapid development of digital technology and the increasing integration of Artificial Intelligence (AI) in education have transformed learning processes, particularly in STEM (Science, Technology, Engineering, and Mathematics) education. This study aims to analyze the development of research on digital literacy in STEM education through a bibliometric analysis and Systematic Literature Network Analysis (SLNA). The study employed a combination of bibliometric methods, SLNA, and content analysis to identify publication trends, collaboration networks, dominant research themes, and emerging future directions. Data were collected from the Scopus database following the PRISMA 2020 guidelines. A total of 106 relevant articles published between 2019 and 2025 were selected and analyzed using VOSviewer and Orange Data Mining. The findings indicate a significant increase in publications related to digital literacy, AI, and STEM education, particularly in 2025. Bibliometric mapping revealed three major research clusters: technology-integrated teaching and digital literacy in science and engineering education, the role of digital competence and computational thinking in STEM higher education, and the integration of AI and AI literacy in digital literacy development. Topic modeling using Latent Dirichlet Allocation (LDA) identified ten dominant research topics, with technology-based STEM learning and AI-supported education emerging as the most prominent themes. The results also highlight the growing emphasis on AI integration, computational thinking, digital competence, and innovative pedagogical approaches in modern STEM education. Overall, the study demonstrates that research on digital literacy in STEM education is rapidly evolving toward interdisciplinary and AI-driven learning environments. However, challenges remain regarding digital inequality, AI literacy integration, and sustainable pedagogical implementation. This study contributes to the understanding of current research trends and provides future research directions for strengthening digital literacy and AI integration in STEM education.

**Keywords:** AI; Bibliometric analysis; Computational thinking; SLNA STEM

## Introduction

The rapid development of digital technology and the increasing integration of Artificial Intelligence (AI) in education have changed the way the learning process is carried out, especially in STEM (Science, Technology, Engineering, and Mathematics) education. In the digital era, students are not only required to master conceptual knowledge, but must also have strong digital literacy skills to access, evaluate, create, and communicate information critically through digital technology. Therefore, digital literacy is an important competency that supports critical thinking, problem-solving, collaboration, and innovation skills in the STEM learning environment.

The importance of digital literacy in STEM education is increasingly gaining attention from researchers in various countries, especially after the COVID-19 pandemic which accelerated the adoption of technology-based learning and online learning. Previous research has shown a significant increase in publications related to digital literacy, e-learning, and digital

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transformation in education (Hung et al., 2025; Wang & Si, 2023). In addition, integrated STEM learning has been proven to be able to improve students' digital literacy skills through the use of technology, inquiry-based learning, and collaboration in problem-solving (Anistyasari & Hidayati, 2025). These findings suggest that digital literacy is no longer an additional skill, but has become a core part of 21st-century STEM learning.

Although the number of research continues to increase, studies on digital literacy in STEM education are still spread across a variety of different disciplines, methodologies, and educational contexts. Most research focuses only on the use of specific technologies or local implementations without providing a comprehensive picture of the development of that field of research. As a result, understanding of research trends, collaboration networks, dominant themes, influential publications, and future research directions is still limited. This condition shows the importance of conducting a more systematic and comprehensive study through Literature Network Analysis (LNA) and bibliometric analysis.

Literature Network Analysis and bibliometric studies are important because they are able to map the intellectual structure and development of scientific knowledge in a field of research. Through bibliometric techniques such as citation analysis, author collaboration analysis, and keyword co-occurrence analysis, researchers can identify the main themes of the research, influential authors, dominant countries and institutions, as well as emerging publication trends (Liu & Xu, 2025; Wu et al., 2025). In addition, the use of visualization tools such as VOSviewer and orange data mining allows researchers to see the relationships between studies and discover new topics that have the potential to be the direction of future research. Bibliometric analysis also helps identify research gaps so that it can provide important insights for researchers, educators, and policymakers in designing more effective educational strategies.

Several recent studies also confirm that the study of digital literacy is multidisciplinary (Yang et al., 2025) stated that digital literacy research is increasingly connected to the fields of communication, psychology, technology, and pedagogy, so that a cross-disciplinary collaborative approach is needed. In addition, Govender (2025) shows that digital literacy has a strong relationship with STEM skills, especially in improving students' problem-solving skills and technological competence. However, bibliometric studies that specifically focus on digital literacy in STEM education are still relatively limited, opening up important research opportunities to be developed.

Therefore, this study aims to conduct Literature Network Analysis and bibliometric studies on digital literacy in STEM education to analyze publication trends, patterns of research collaboration, sources of influential publications, and research themes that develop in this field. Through systematic literature mapping, this research is expected to contribute to the development of future research directions and support educators and policymakers in strengthening the integration of digital literacy in STEM education.

## Method

This study applies a combination of Systematic Literature Network Analysis (SLNA) and content analysis methods to explore the development of research on digital literacy in STEM education more comprehensively (Lendra et al., 2023). The combination of these two methods allows researchers not only to see the development of publications quantitatively, but also to understand the relationships between topics, research collaboration patterns, and the direction of study development that emerges from time to time. The SLNA approach is used to map the structure of knowledge in the field of research, identify dominant trends, and find new research opportunities that are still rarely studied (Wakid et al., 2024). On the other hand, content analysis helps to interpret the meaning and focus of the research so as to provide a deeper understanding of the main issues that are developing in the literature.


**Figure 1.** Selection process

The research process begins with the collection of article data through the Scopus database by following the PRISMA 2020 guidelines so that the article selection process takes place in a systematic, transparent, and structured manner. The metadata of articles that have met the criteria is then analyzed using the VOSviewer software to generate a visualization of the bibliometric network based on the relationship of keywords, authors, publication sources, and affiliated countries. Furthermore, text analysis was carried out using Orange Data Mining through pre-processing stages, word frequency analysis, and topic modeling to identify the most discussed research themes (Baker & Yacef, 2009;

Bosisio, 2024). All stages of this research are visualized in Figure 1 as an illustration of the main flow of the methodology used in the research.

This initial stage involves the implementation of PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) to ensure that the systematic review process is carried out in a structured, transparent, and systematic manner (Page et al., 2021). In the initial stage, the process of identifying articles is carried out through a search on the Scopus database because this database has a wide scope of scientific publications and is relevant to the fields of education, technology, and digital literacy. The article search was carried out using keywords related to digital literacy and STEM Education so that a number of initial articles were obtained which were then further selected according to the inclusion and exclusion criteria of the research. The keywords used to search for the article are: *("digital literacy" OR "digital competence" OR "digital skills" OR "AI literacy") AND (STEM OR "STEM education" OR "science education)*

To minimize the potential for bias in the article screening process, this study involved four authors who played an active role at each stage of selection. The first author was in charge of searching for articles in the Scopus database and compiling keywords and research inclusion criteria. The second author conducted an initial check on the suitability of the year of publication, the field of study, and the type of article document. The third author is responsible for screening titles and abstracts to ensure the relevance of the article to the topic of digital literacy and STEM Education. Meanwhile, the fourth author carried out the final validation of the articles that passed the selection and ensured the consistency of the data before the article was entered into the analysis stage.

The article selection process in this study follows the PRISMA stage which consists of identification, screening, eligibility, and included. At the identification stage, 801 articles were obtained from the Scopus database. Furthermore, an initial screening was carried out by removing 183 articles that were not in accordance with the 2019–2025 publication year range and 70 articles that were not included in the field of social science and computer science. After the process, 548 articles are left to enter the next stage of screening. At the screening stage, articles were examined based on their titles and abstracts, then as many as 178 articles were issued because they were not in accordance with the focus of the research, namely not related to digital literacy and STEM education.

The next stage is eligibility, which is a more in-depth assessment of the feasibility of the article on 370 articles that have passed the previous stage. At this stage, a total of 63 articles were removed because 52 articles were not available in the form of complete documents and 11 articles were not in English. After the feasibility evaluation process was completed, 169 articles were obtained that were eligible for further analysis. At the final stage (included), a final selection was carried out so that 106 articles were obtained that were declared relevant and suitable for use in the research to analyze the development of studies on digital literacy and STEM education.

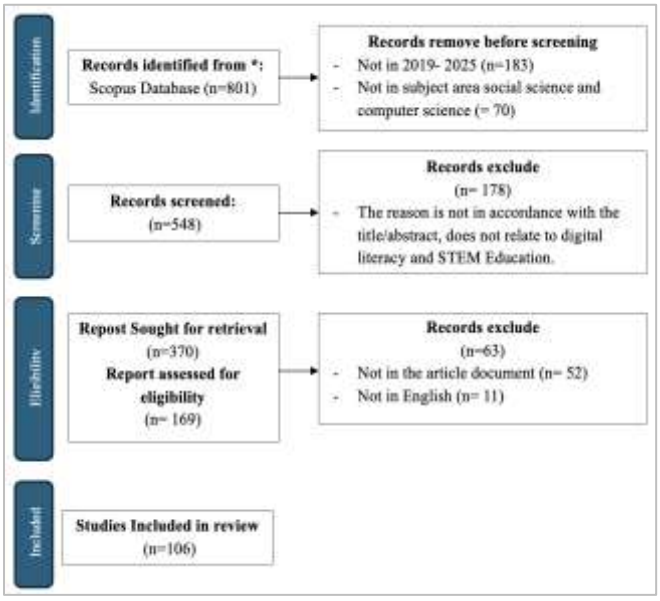


**Figure 2**. PRISMA 2020

Once the filtering process is complete, the article data that meets the criteria is exported in .ris format and analyzed through two main stages. The first stage uses Systematic Literature Network Analysis (SLNA) with the help of VOSviewer software to map bibliometric relationships based on publication sources, affiliated countries, and keyword linkages. The second stage was carried out using Orange Data Mining through a process of pre-processing text, word frequency analysis, and the application of the Latent Dirichlet Allocation (LDA) method to identify the main themes of the research, which were then visualized in the form of a technical workflow.

## Result and Discussion

*Performing Analysis*

Based on the analysis of publication data from 106 articles obtained, it can be seen that the volume of publications regarding digital literacy, artificial intelligence, and STEM education has increased significantly from year to year. In 2019 there was only 1 publication, then it increased to 7 publications in 2020. In 2021, there was a slight decline with 4 publications, but it increased again in 2022 with 15 publications.

Furthermore, the number of publications in 2023 and 2024 is relatively stable with 14 publications each. The most significant increase will occur in 2025 with a total of 51 publications, which shows the high attention researchers have paid to the integration of digital literacy, AI, and STEM education in recent years.

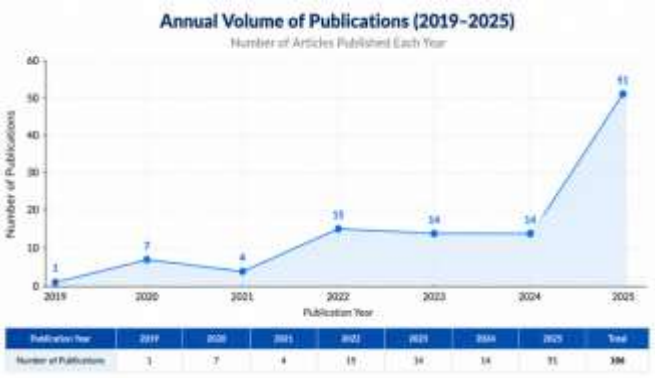


**Figure 3**. Publications from 2019-2025

Based on the analysis of publication data, there are some journals that are most productive in publishing research related to digital literacy, artificial intelligence, and STEM education. The journals with the highest number of publications are *Sustainability (Switzerland)* and *Education Sciences* with 7 articles each. Furthermore, *Frontiers in Education and Computers and Education*: *Artificial Intelligence* published 4 articles each.

Several other journals such as *IEEE Access, International Journal of STEM Education, Journal of Technology and Science Education, and Eurasia Journal of Mathematics, Science and Technology Education* each have 3 publications. These results show that research on digital literacy, AI, and STEM education is widely published in journals that focus on education, educational technology, and digital transformation in learning.

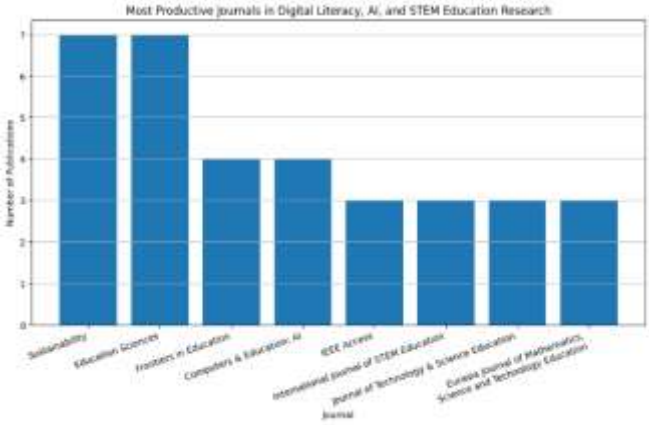


**Figure 4.** Journal of productive publications

Table 1 shows the distribution of publications by country from a total of 106 articles analyzed in this study. Spain is the country with the highest number of documents, with 15 articles, followed by the United States with 12 articles and the United Kingdom with 10 articles. Australia contributed 8 articles, Germany 7 articles, Indonesia 6 articles, while South Africa and China each produced 5 articles. This data shows that research on digital literacy and STEM education has developed in various countries, both in Europe, America, Asia, and Africa.

**Table 1.** Document from Each Country

| Country | Documents | Citations | CPD (TC/TD) | Total Link Strength |
|---|---|---|---|---|
| United Kingdom | 10 | 134 | 13.4 | 5 |
| United States | 12 | 125 | 10.4 | 4 |
| Indonesia | 6 | 60 | 10.0 | 3 |
| South Africa | 5 | 46 | 9.2 | 3 |
| Australia | 8 | 84 | 10.5 | 1 |
| Germany | 7 | 184 | 26.3 | 1 |
| Spain | 15 | 106 | 7.1 | 1 |
| China | 5 | 56 | 11.2 | 0 |

Based on the network visualization and overlay visualization in VOSviewer, it can be seen that there is a collaboration network between countries in research related to digital literacy and STEM education. The United Kingdom is the main link in the collaboration network because it is connected to Indonesia, Australia, South Africa, and the United States, while the United States also has relations with Spain and South Africa. The size of the node indicates the level of publication contribution, where the United States and Spain have a sizable contribution compared to other countries. In addition, the overlay visualization shows the development of the time of the publication of the study, where the United Kingdom was active in the study first, while the United States and Spain showed more dominant contributions in the most recent period. Indonesia and Australia are in the middle development phase, so this visualization illustrates that research on digital literacy and STEM education continues to develop through international collaboration between countries.

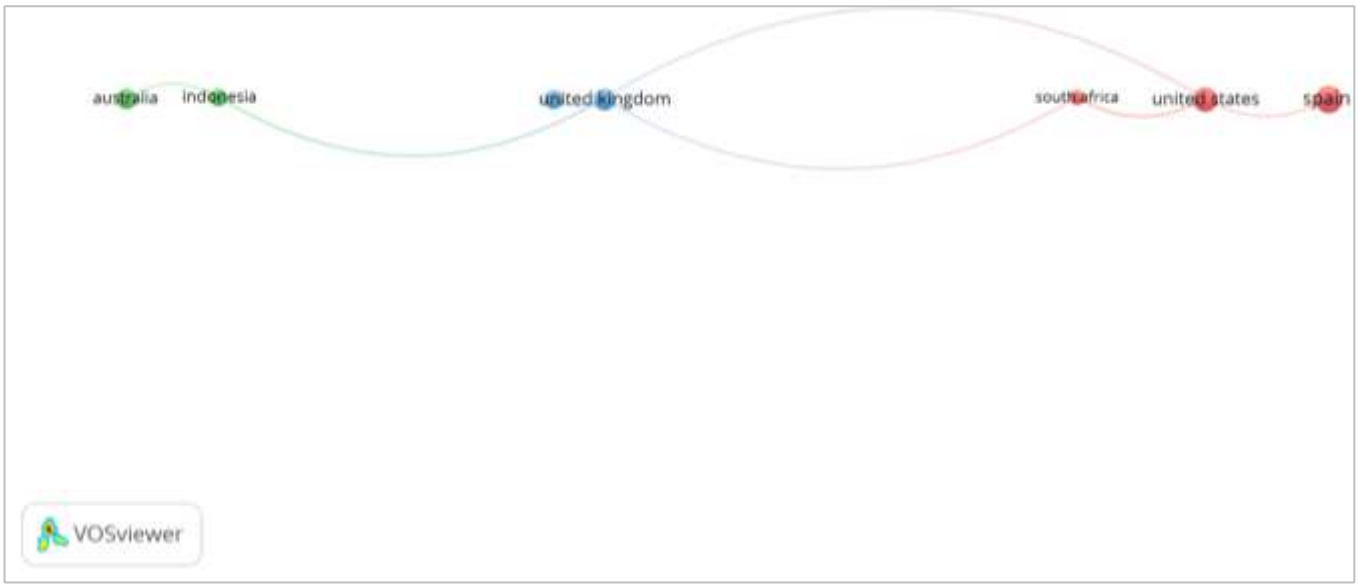


**Figure 5**. Network visualization

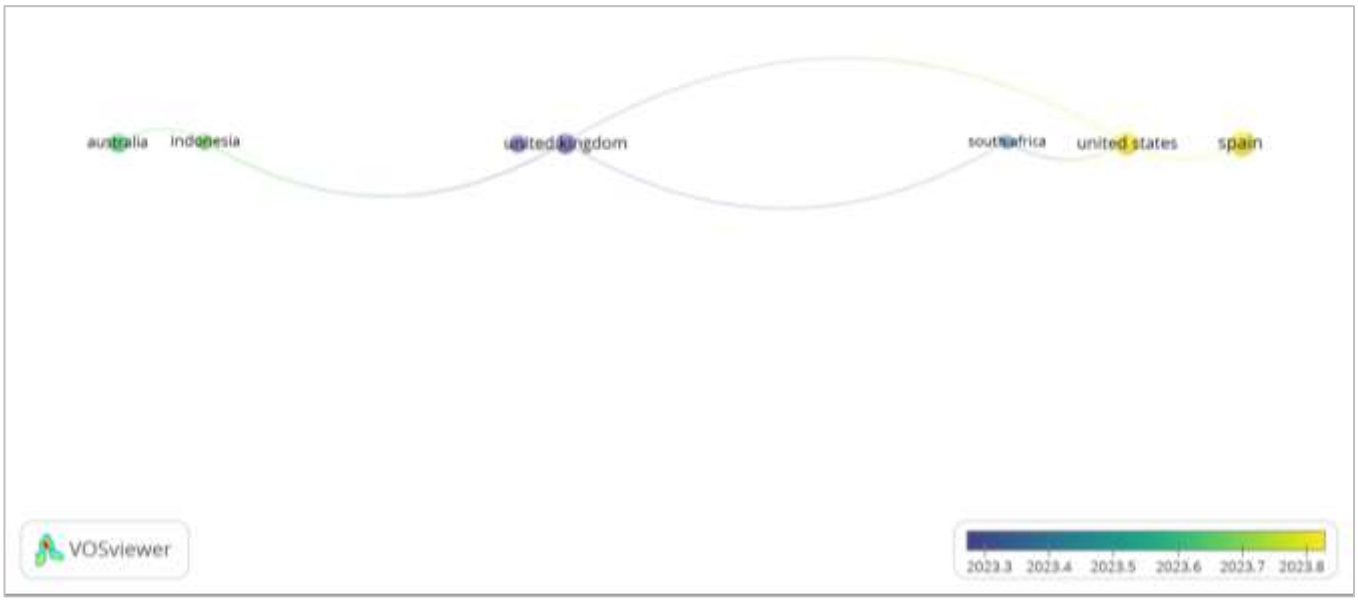


**Figure 6.** Overlay Visualization

*Mapping Science*

The visualization on VOSviewer shows the results of the keyword co-occurrence analysis from 106 articles that have been selected in the research on digital literacy and STEM education. In the initial stage, researchers set a minimum limit of 5 occurrences of a keyword (*minimum number of occurrences of a keyword = 5*). Of the total 669 keywords found, 19 keywords met the threshold and were selected for further analysis based on the total link strength between the keywords. The keywords that have the highest frequency of occurrences are artificial intelligence and digital literacy with 23 occurrences each, followed by STEM with 20 occurrences, science education with 18 occurrences, and AI literacy with 17 occurrences. In addition, keywords such as students, engineering education, higher education, and computational thinking also showed a strong relationship in this study.

The results of the *network visualization* show that there are three main clusters that are interconnected. The first cluster in red focuses on the theme of education and learning, which includes keywords such as students, curricula, teaching, engineering education, education computing, science education, and digital literacies. The second green cluster emphasizes more on the development of digital competencies and STEM education, with keywords such as digital literacy, higher education, STEM education, digital competence, computational thinking, and sustainable development. Meanwhile, the third cluster in blue is related to the

development of artificial intelligence technology in education, which consists of the keywords artificial intelligence, AI literacy, digital skills, education, and STEM. The interconnected relationships between nodes suggest that these topics are closely related in research on digital literacy and STEM education.

In addition, the overlay visualization shows the development of research trends based on the average year of publication from 2023 to 2024. Blue indicates an earlier topic being researched, while yellow indicates a newer and evolving topic. Keywords such as STEM, digital skills, higher education, and computational thinking appear earlier in the research, while keywords such as artificial intelligence, AI literacy, students, curricula, and digital competence show the latest research trends in the 2024 period. Meanwhile, the keywords digital literacy and STEM education are in a transition position that connects initial research and the latest developments. This visualization shows that research on digital literacy and STEM education continues to develop towards the integration of artificial intelligence, AI literacy, and strengthening digital competencies in modern education.

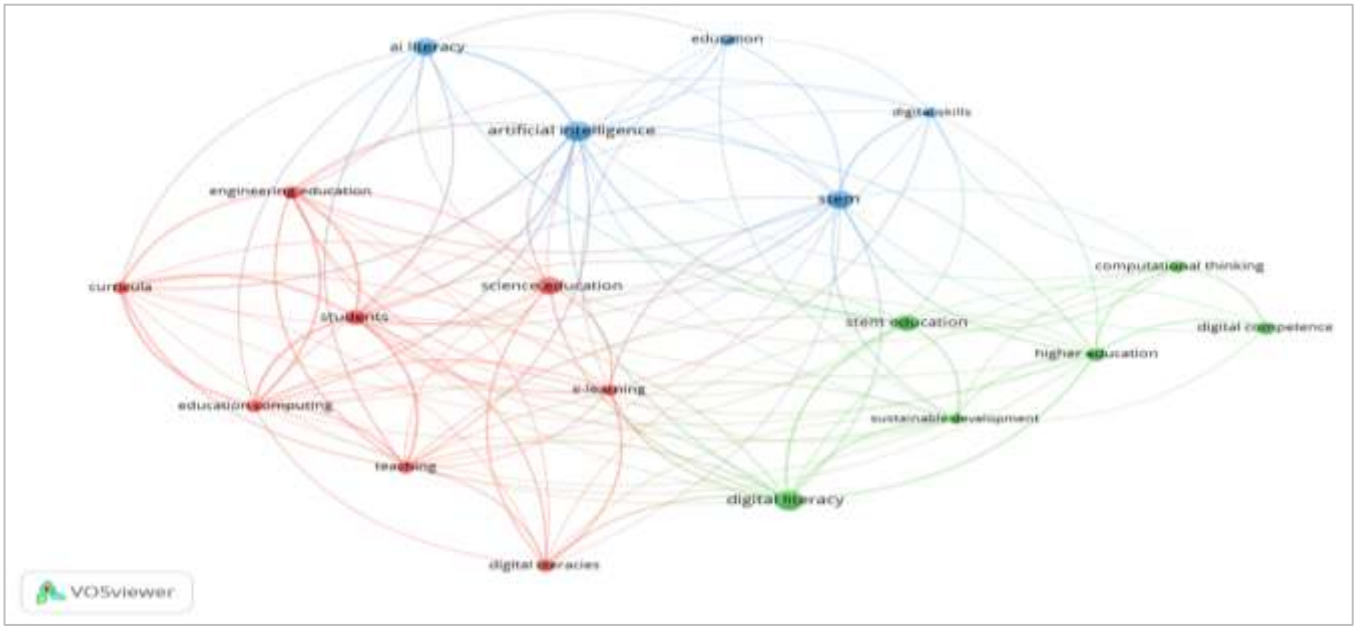


**Figure 7**. Network visualization co-occurrence

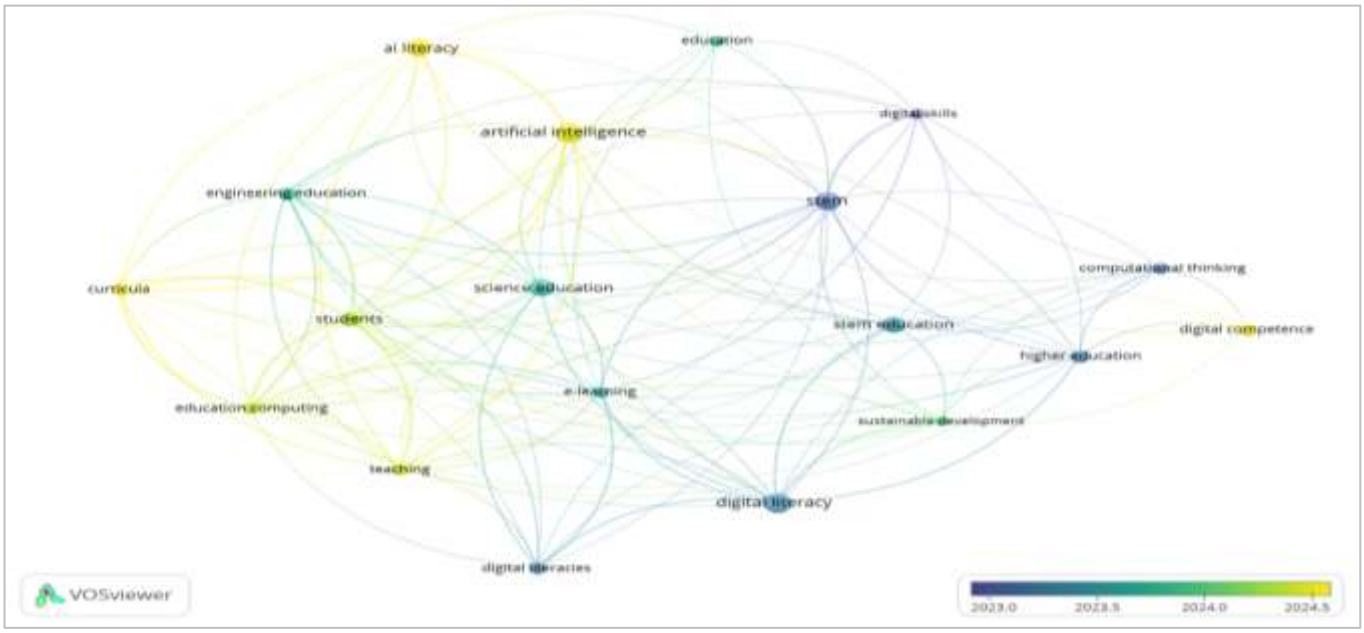


**Figure 8**. Overlay visualization co-occurrence

*Red Cluster: How are Digital Literacy and Technology-Integrated Teaching Approaches Applied to Support the Learning Process in Science And Engineering Education*?

Digital literacy and technology-based learning approaches are increasingly being applied in science and engineering education to support innovative and effective learning processes. Digital literacy is not only related to technical capabilities, but also the ability of educators and students to access, evaluate, and utilize digital technology in the learning environment (Wider et al., 2026). In science and engineering education, technologies such as artificial intelligence (AI), virtual reality (VR), augmented reality (AR), simulation, robotics, and gamification are widely integrated to improve student engagement, conceptual understanding, collaboration skills, and critical thinking skills (Hoque et al., 2025; Mkhize & Ngema, 2025). In addition, professional development programs for teachers and lecturers have an important role in improving digital pedagogical competencies and ensuring that technology integration can be effectively applied in the learning process (Temirkhanova et al., 2024).

The integration of digital literacy is also reflected in curriculum design through interdisciplinary, project-based, and hybrid learning approaches that combine online and face-to-face learning (Van Rooyen et al., 2022). Real-world-based projects and AI-based learning platforms are implemented to connect theoretical concepts with hands-on practice while encouraging students' computational thinking skills and digital competencies (Christie et al., 2025; Kushwah et al., 2025). However, challenges such as the digital divide, limited access to technology, and difficulties in managing hybrid learning remain major obstacles (Shnaikat et al., 2024). Overall, the results of the study show that the integration of technology-based learning and digital literacy is able to improve technical skills, critical thinking skills, learning engagement, and students' readiness to face careers in the STEM field in the digital era.

*Green Cluster: The Contribution of Digital Literacy, Digital Competence, and Computational Thinking to STEM Education in Higher Education*

Digital literacy, digital competence, and computational thinking have important contributions to the development of STEM education in higher education. Digital literacy includes not only the ability to use digital technology, but also the ability to search, evaluate, and utilize information effectively to support academic and professional processes (Li et al., 2024). In STEM education, digital literacy helps improve conceptual understanding, problem-solving skills, student engagement, and academic performance through the use of mobile applications, classroom response systems, and various digital learning platforms (Bojórquez-Roque et al., 2025; Sun et al., 2025). In addition, digital competencies play a role in developing 21st century skills such as creativity, digital security, collaboration, and critical thinking skills that support students' readiness to face the technology-based world of work (Santos et al., 2022). Pedagogical approaches such as flipped classroom, gamification, and project-based learning are also increasingly being applied to increase student motivation and learning outcomes in STEM Education (Ramdana & Furqon, 2026).

Meanwhile, computational thinking contributes to developing the skills of logical thinking, problem solving, abstraction, pattern recognition, and algorithmic thinking which are important foundations in STEM learning (Bojórquez-Roque et al., 2025). The integration of Computational Thinking with Artificial Intelligence and Programming helps students understand new technologies and improve their innovation and problem-solving skills in an interdisciplinary manner (Pinheiro & Santos, 2025; Zerega et al., 2025). The relationship between digital literacy, digital competence, and computational thinking also shows that the higher the students' digital competence, the better their ability to think critically and solve complex problems (Sabyrkhanova et al., 2026). Therefore, the integration of these three competencies into the STEM curriculum in higher education is an important step to improve the quality of learning, reduce the digital divide, and prepare students to face the challenges of the digital transformation era.

*Blue Cluster: Integration of Artificial Intelligence (AI) and AI Literacy in the Development of Digital Literacy in Education*

The integration of artificial intelligence (AI) and AI literacy has a significant influence on the development of digital literacy in contemporary education. AI technologies such as generative AI, adaptive learning systems, and intelligent tutoring systems help improve students' ability to think critically, problem-solve, creativity, and engage in the use of digital technology (Shatila & Hernández-Lara, 2025). In addition, the use of AI in learning also supports a more adaptive learning and evaluation process so that students can develop digital literacy skills more effectively (Wu & Zhang, 2025). AI literacy includes not only technical ability to use AI, but also the ability to understand AI principles, evaluate AI-generated information, and ethical awareness in the use of digital technology (Saddhono et al., 2024). Therefore, the ability to think critically and evaluatively is an important aspect in the development of digital literacy in the era of AI-based education.

In the context of education, AI literacy is increasingly seen as a basic competency for educators

and learners. Pre-service teacher education and professional training programs are beginning to integrate AI literacy to improve teachers' ability to effectively and responsibly apply AI in learning (Gulen & Kucuk, 2026; Le et al., 2026). The integration of AI in the curriculum also encourages a more transformative, collaborative, and experiential approach to learning to prepare students for the challenges of the digital society (Ruhi et al., 2025). However, challenges such as limited access to technology, lack of training, and resistance to change are still obstacles to the implementation of AI in education (Karroum & Elshaiekh, 2023; Ngoveni, 2025). Overall, the integration of AI and AI literacy contributes to strengthening digital literacy by improving critical thinking skills, ethical awareness, technological competence, and the readiness of students and educators to face educational transformation in the era of artificial intelligence.

*Content Analysis*

Before topic modeling using the Latent Dirichlet Allocation (LDA) method, content analysis begins with the creation of word cloud visualizations to ensure that the text preprocessing process, such as data cleaning, normalization, and tokenization, has been done properly. Word cloud visualization is used as an initial tool to identify the words that appear most often from the title and abstract of the article, as well as validate the suitability of the research theme with the focus of the study that has been set.

In the transformation stage, the entire text is changed to lowercase and special characters or accents are removed to maintain data consistency. Furthermore, the tokenization process is carried out using the word punctuation method to separate the words in the document. In the filtering stage, English stopwords, numbers, symbols, and characters that are irrelevant are removed using regular expression (regexp). In addition, a relative document frequency setting is applied to select words that have a relevant level of occurrence in the research document.


**Figure 9**. Word cloud

**Table 2.** Topic and Topic Keyword

| Topic | Topic Label | Topic Keywords |
|---|---|---|
| 1 | Digital Education and AI Development | education, development, stem, science, students, digital, intelligence, artificial, computing, engineering |
| 2 | Technology-Based Learning in STEM | learning, engineering, education, computing, students, science, digital, stem, development, artificial |
| 3 | AI and Digital Learning Development | education, learning, intelligence, development, artificial, stem, students, digital, science, engineering |
| 4 | Artificial Intelligence in Education | intelligence, artificial, education, development, learning, science, digital, stem, engineering, students |
| 5 | Digital STEM and Engineering Education | science, digital, engineering, stem, students, intelligence, artificial, education, development, learning |
| 6 | Computing and Engineering Education | education, artificial, intelligence, students, computing, engineering, science, development, learning, stem |
| 7 | AI-Supported STEM Learning | artificial, intelligence, learning, education, students, stem, computing, science, development, engineering |
| 8 | Science and Engineering Learning | science, engineering, education, students, computing, stem, learning, intelligence, artificial, digital |
| 9 | Digital Learning and STEM Development | digital, learning, stem, education, development, computing, engineering, students, science, intelligence |
| 10 | Educational Development and AI Integration | education, learning, development, intelligence, stem, artificial, digital, students, engineering, science |

The results of word frequency analysis from research data that have gone through the preprocessing process. The word education has the highest weight with a score of 47, followed by learning as many as 30, engineering as many as 24, and science as many as 21. In addition, the words digital, artificial, and intelligence also have a high frequency, which shows that research focuses a lot on the integration of artificial intelligence and digital literacy in education. Words such as development, students, STEM, and computing also

show the relationship between research and the development of technology-based learning in the fields of science and engineering. These results indicate that the dominant themes in the research are related to education, digital learning, technology development, and the application of AI in STEM education.

After the data cleaning process is completed, topic modeling analysis is carried out and 10 main topics with the best coherence score are obtained, which show the level of relevance and consistency between words in each topic so as to be able to describe research patterns and trends more systematically in the study of digital literacy, artificial intelligence, and STEM education.

Based on the results of the Marginal Topic Probability, the probability distribution shows that not all topics have the same level of dominance in the research document set. Topic 2 is the most dominant topic with the highest probability of around 0.19, followed by Topic 7, Topic 8, and Topic 9 which also have a high probability. The dominance of these topics shows that the research focuses more on the themes of education, digital learning, STEM, and the integration of artificial intelligence in the learning process. In contrast, Topic 3, Topic 4, and Topic 10 have a very low probability, suggesting that they are only covered in a small part of the document and have a more limited contribution to the overall study. Meanwhile, Topic 1, Topic 5, and Topic 6 are at a medium probability level, indicating that these themes still have an important role but are not as strong as other dominant topics. This probability distribution shows that there is a concentration of research on certain themes that are considered most relevant to the development of technology-based education and digital literacy.

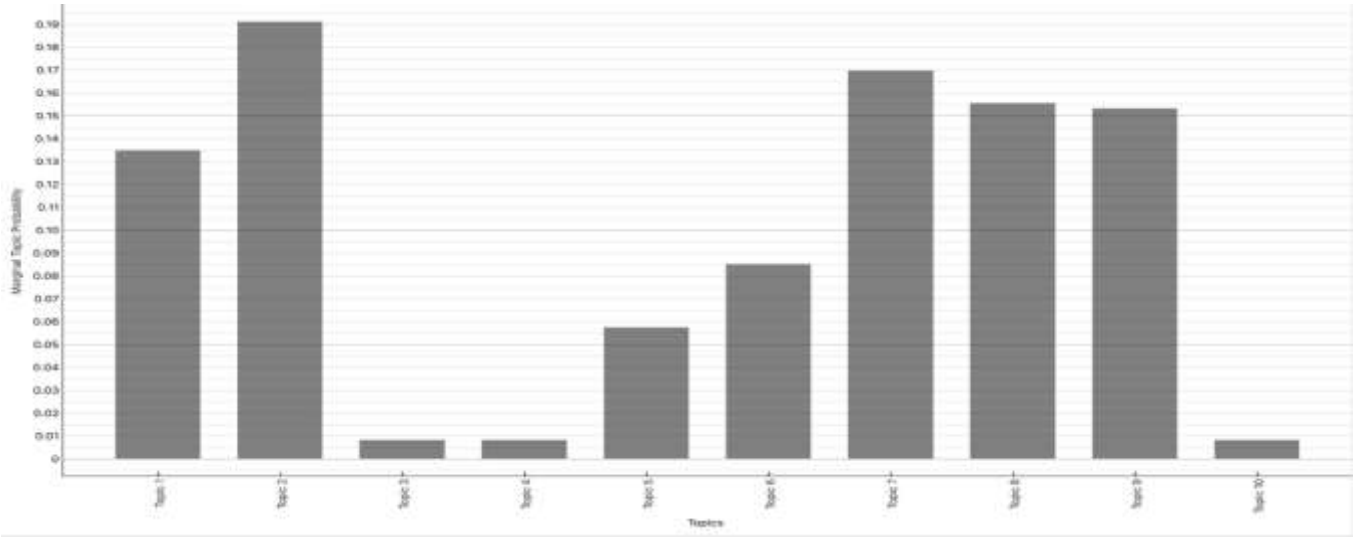

**Figure 10**. MTP

The results of the Intertopic Distance Map further strengthen the findings by showing the semantic relationships between the modeled topics using the Latent Dirichlet Allocation (LDA) method. The size of the circles in the visualization indicates the degree of dominance of the topic, while the distance between the circles represents the degree of proximity of the research theme. Topic 2, Topic 7, Topic 8, and Topic 9 appear to be larger in size and relatively dispersed positions, which indicates that these topics have a wide scope of discussion and are the main focus of the research. On the other hand, Topic 3, Topic 4, and Topic 10 are close together in the middle with a small size, which indicates a thematic connection but with a low intensity of discussion. This visualization shows that research on digital literacy, artificial intelligence, and STEM education has inter-topic relationships that are integrated with each other, especially in the aspects of digital learning, technological competency development, and the application of AI in modern education. Thus, topic modeling not only depicts the dominant theme in the research, but also shows the pattern of relationships and the direction of development of technology-based education studies more comprehensively.

Overall, the results of the analysis show that research on digital literacy, artificial intelligence, and STEM education has undergone significant developments, especially in the integration of digital technology and AI in the learning process. However, there is still a need to develop a more integrated learning approach between technology competencies, AI literacy, computational thinking, and digital pedagogy development in order to be able to support STEM learning more effectively and sustainably. In addition, the results of the analysis also show the importance of strengthening the curriculum, developing digital competencies, and implementing innovative learning

models that are able to bridge educational needs with modern technological developments. Table 3 summarizes emerging research trends and provides future development directions related to digital literacy, artificial intelligence, and STEM education.

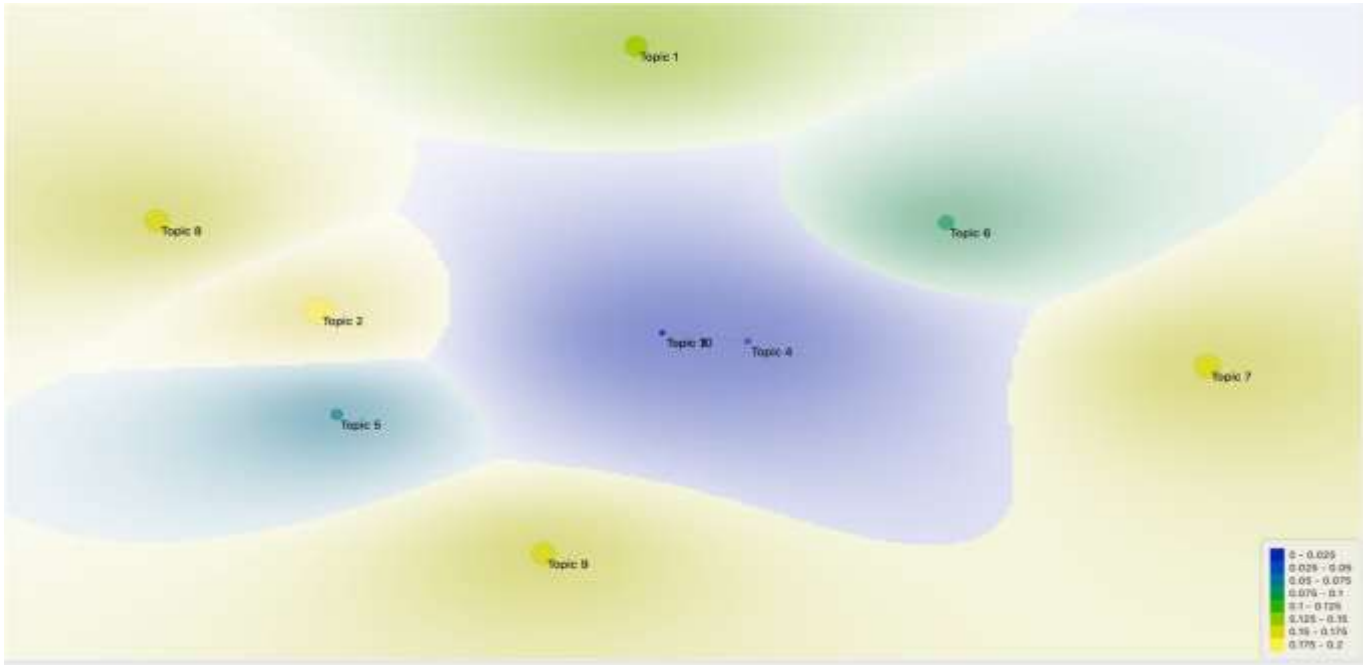


**Figure 11**. Intertopic distance map

**Table 3.** Emerging Research Trends and Promising Future Directions

| Topic | Emerging Research Trends | Promising Future Directions |
|---|---|---|
| Topic 1 | Integration of AI and digital literacy in STEM education development | Development of AI-driven STEM curricula and intelligent learning environments |
| Topic 2 | Technology-enhanced learning in engineering and computing education | Expansion of adaptive and personalized learning systems in engineering education |
| Topic 3 | AI-supported digital learning and student-centered education | Exploration of AI-assisted collaborative and experiential learning models |
| Topic 4 | Artificial intelligence applications in educational innovation | Ethical AI implementation and AI literacy frameworks for education |
| Topic 5 | Digital transformation in science and engineering education | Development of interdisciplinary STEM learning using immersive technologies |
| Topic 6 | Computing and AI integration for student competency development | Enhancement of computational and problem-solving skills through AI-based platforms |
| Topic 7 | AI-enhanced STEM learning and intelligent education systems | Research on generative AI and automation in STEM pedagogy |
| Topic 8 | Science and engineering learning supported by digital technologies | Application of simulation, virtual laboratories, and smart learning systems |
| Topic 9 | Digital learning ecosystems and STEM development | Strengthening digital competence and hybrid learning in higher education |
| Topic 10 | Educational development through AI and digital innovation | Sustainable and inclusive AI integration in future education systems |

In summary, the results of the content analysis show that the research is dominated by the themes of digital education, digital literacy, STEM education, and the integration of artificial intelligence in the learning process. Through word cloud visualization, network visualization, and topic modeling using the Latent Dirichlet Allocation (LDA) method, it can be seen that most of the research focuses on the development of technology-based learning, digital competence, computational thinking, and the application of AI in modern education. However, there is still a research gap in the development of AI literacy integration, AI-based STEM learning, and the implementation of digital pedagogy that is more collaborative and sustainable. This gap shows the need for the development of more integrated AI-based education programs,

multidisciplinary research, and long-term studies to strengthen digital literacy and technological competence in supporting educational transformation in the digital era.

## Conclusion

This study shows that the study of digital literacy in STEM education has undergone significant development in recent years, especially after the increasing integration of digital technology and artificial intelligence (AI) in the learning process. The results of the bibliometric analysis show an increase in the number of publications from year to year with the dominance of research on the themes of digital education, technology-based learning, AI literacy, computational thinking, and digital competency development. In addition, bibliometric visualization through VOSviewer shows that research in this area has a strong link between STEM education, digital literacy, and the application of AI in modern learning environments. The results of the science mapping map identified three main research clusters, namely the implementation of digital literacy and technology-based learning in science and engineering education, the contribution of digital competence and computational thinking to STEM education, and the integration of AI and AI literacy in the development of digital literacy. Furthermore, content analysis using the Latent Dirichlet Allocation (LDA) method resulted in ten main topics that show that the current research focus is more directed towards the development of digital learning, AI-based adaptive learning systems, strengthening technological competencies, and technology-based STEM pedagogical innovations. Overall, this study confirms that digital literacy has become a core competency in 21st century STEM education. The integration of AI, computational thinking, and digital technology provides a great opportunity to improve the quality of learning, critical thinking skills, creativity, and readiness of students to face global digital transformation. However, there are still challenges in the form of digital divides, limited infrastructure, low AI literacy competencies, and a lack of sustainable digital pedagogy integration. Therefore, it is necessary to develop a more adaptive curriculum, strengthen educator training, and multidisciplinary and longitudinal research to support the implementation of digital literacy and AI in STEM education more effectively and sustainably in the future.

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The authors declare no conflict of interest.

## References

Anistyasari, Y., Hidayati, S. C., & Ekohariadi. (2025). The Effect of Integrated STEM Implementation on Digital Literacy Skills: A Regression Analysis. *2025 IEEE Integrated STEM Education Conference (ISEC)*, 1–5. https://doi.org/10.1109/ISEC64801.2025.11147422

Baker, R. S. J. D., & Yacef, K. (2009). The State of Educational Data Mining in 2009 : A Review and Future Visions. *Journal of Educational Data Mining*, *1*(1), 3–16. https://doi.org/10.5281/ZENODO.3554657

Bojórquez-Roque, M. S., Oliva-Córdova, L. M., Garcia-Cabot, A., & Garcia-Lopez, E. (2025). Mobile Applications and Classroom Response Systems to Enhance Learning Performance: An Experience from Digital Competences. *International Journal of Engineering Education*, *41*(2), 266–279. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-105001056664&partnerID=40&md5=ee21df680d13f91ee4199819c24d6b98

Bosisio, J. (2024). A research landscape on customer co-creation value: a systematic literature network analysis. *Italian Journal of Marketing*, *2024*(3), 339–368. https://doi.org/10.1007/s43039-024-00092-9

Christie, M. D., Mengersen, B. von, Levins, M., & Puddicombe, C. (2025). Students as digital designers in Engineering. In *Creative Technologies Education* (pp. 190–207). Routledge. https://doi.org/10.4324/9781003490715-13

Govender, I. (2025). Digital Literacy and STEM Skills–What is the Connection? A Systematic Review. *Technology, Knowledge and Learning*. https://doi.org/10.1007/s10758-025-09879-x

Gulen, H. N., & Kucuk, S. (2026). Integrating artificial intelligence into preservice teacher education: enhancing AI literacy and digital material design competency. *Education and Information Technologies*.

https://doi.org/10.1007/s10639-026-14020-1

Hoque, S., Yang, H., & Yousefi, P. (2025). Digital Technologies in Engineering Education: A Scoping Review of Integrated Dynamic Teaching. *Proceedings of the Canadian Engineering Education Association (CEEA)*, *2025*. https://doi.org/10.24908/pceea.2025.19640

Hung, D. Van, Long, D. T., Tuyet, B. T. A., Mai, N. H., Yen, T. T. H., Van, V. T. H., & Hai, N. T. (2025). Digital literacy for higher students: A bibliometric analysis from 1978 to 2023. *College & Undergraduate Libraries*, *32*(3–4), 103–132. https://doi.org/10.1080/10691316.2025.2550935

Karroum, S. Y. A., & Elshaiekh, N. E. M. (2023). Digital Transformation in Education: Discovering the Barriers that Prevent Teachers from Adopting Emerging Technologies. *2023 24th International Arab Conference on Information Technology (ACIT)*, 1–5. https://doi.org/10.1109/ACIT58888.2023.10453908

Kushwah, S., Zakarya, K., Said, E. G., Fadilah, E. R., Ravichandra, B. V, & Attri, R. K. (2025). Innovative Pedagogical Strategies in Science Education: Leveraging Artificial Intelligence for Enhanced Digital Literacy. *2025 Tenth International Conference on Science Technology Engineering and Mathematics (ICONSTEM)*, 1–8. https://doi.org/10.1109/ICONSTEM65670.2025.11374559

Le, T. H., Huynh, L., Dang, B., Pham, H., Nguyen, N. T. V., & Nguyen, A. (2026). Development and evaluation of artificial intelligence literacy training for teacher education students. *British Journal of Educational Technology*. https://doi.org/10.1111/bjet.70047

Lendra, L., Wibowo, M. A., & Hatmoko, J. U. D. (2023). A Systematic Literature Network Analysis: Research Mapping of International Roughness Index. *Instrumentation Mesure Métrologie*, *22*(03), 81–94. https://doi.org/10.18280/i2m.220301

Li, Y., Anuar, N. A. B., Mansor, A. Z. B., & Xing, J. (2024). Predicting Digital Literacy in Higher Education: The Role of Personal Factors. *Eurasian Journal of Educational Research*, *114*, 156–178. https://doi.org/10.14689/ejer.2024.114.10

Liu, C., & Xu, Y. (2025). A visual analysis of the research literature on teachers' digital literacy (2015–2024). *Frontiers in Education*, *10*. https://doi.org/10.3389/feduc.2025.1597121

Mkhize, I. G., & Ngema, P. T. (2025). The Critical Role of Digital Literacy in Transforming Chemical Engineering Education at Durban University of Technology: A Systematic Literature Review. *2025 World Engineering Education Forum - Global Engineering Deans Council (WEEF-GEDC)*, 1–6. https://doi.org/10.1109/WEEF-GEDC66748.2025.11256329

Ngoveni, M. (2025). Bridging the AI Knowledge Gap: The Urgent Need for AI Literacy and Institutional Support. *The International Journal of Technologies in Learning*, *32*(2), 83–100. https://doi.org/10.18848/2327-0144/CGP/v32i02/83-100

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*, *372*, *n71*, n71. https://doi.org/10.1136/bmj.n71

Pinheiro, M. M., & Santos, V. (2025). Integrating Computational Thinking and Artificial Intelligence into Mathematics Education: A Pathway for the 21st-Century. In *Commun. Comput. Info. Sci.: 2479 CCIS* (pp. 82–92). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-3-032-02675-0_7

Ramdana, A. D., Munir, & Furqon, C. (2026). Advancing digital literacy in higher education through pedagogical innovations and institutional strategies between 2014 and 2025. *Discover Education*, *5*(1), 227. https://doi.org/10.1007/s44217-026-01256-9

Ruhi, U., Nieto-Taborda, M., & Nault, K. (2025). From AI Literacy to AI Competency: Fostering Human Agency and Critical Thinking through Andragogical Practice. *2025 5th International Conference on Artificial Intelligence and Education (ICAIE)*, *ICAIE*, 796–800. https://doi.org/10.1109/ICAIE64856.2025.11158693

Sabyrkhanova, L., Zhaidakbayeva, L., Sözer, M. A., Belessova, D., Kurmanbayeva, Z., & Zhidebayeva, A. (2026). Digital Literacy as a Tool for Developing Computational Thinking in Young Learners: A Literature Review. *Open Education Studies*, *8*(1). https://doi.org/10.1515/edu-2025-0121

Saddhono, K., Suhita, R., Rakhmawati, A., Rohmadi, M., & Sukmono, I. K. (2024). AI and Literacy: Developing Critical Thinking and Analytical Skills in the Digital Era. *2024 International Conference on IoT, Communication and Automation Technology (ICICAT)*, *ICICAT*, 360–365. https://doi.org/10.1109/ICICAT62666.2024.10922871

Santos, S., Lucas, M., & Bem-Haja, P. (2022). Bridging the Digital Competence Gap: Tell Us What You Need.

In *15th International Conference on ICT* (pp. 104–111). Computer Science Information Syst. https://doi.org/10.33965/ict_wbc_eh2022_202204l013

Shatila, K., & Hernández-Lara, A. B. (2025). The role of artificial intelligence in shaping digital literacy: enhancing higher education through student interaction and pedagogical innovation. In *Multidisciplinary Movements in AI and Generative AI* (pp. 98–114). Edward Elgar Publishing. https://doi.org/10.4337/9781035358663.00014

Shnaikat, K., Marasco, E., & Barcomb, A. (2024). Development of a Digital Literacy Course to Minimize Digital Inequities Among First-Year Engineering Students. *Proceedings of the Canadian Engineering Education Association (CEEA)*. https://doi.org/10.24908/pceea.2024.18589

Sun, Z., Yuan, R., & Liu, X. (2025). How would future mathematicians embrace digital literacy? An TAM model-based analysis. *Journal of University Teaching and Learning Practice*, *21*(08). https://doi.org/10.53761/x1m1ja93

Temirkhanova, M., Abildinova, G., & Karaca, C. (2024). Enhancing digital literacy skills among teachers for effective integration of computer science and design education: a case study at Astana International School, Kazakhstan. *Frontiers in Education*, *9*. https://doi.org/10.3389/feduc.2024.1408512

Van Rooyen, M., Blaine, D. C., & Wolff, K. (2022). Leveraging digital tools to design an integrative hybrid learning experience. *2022 IEEE IFEES World Engineering Education Forum - Global Engineering Deans Council (WEEF-GEDC)*, 1–6. https://doi.org/10.1109/WEEF-GEDC54384.2022.9996253

Wakid, M., Sofyan, H., Widowati, A., & Zaida Ilma, A. (2024). Learning-oriented assessment: a systematic literature network analysis. *Cogent Education*, *11*(1). https://doi.org/10.1080/2331186X.2024.2366075

Wang, C., & Si, L. (2023). A Bibliometric Analysis of Digital Literacy Research from 1990 to 2022 and Research on Emerging Themes during the COVID-19 Pandemic. *Sustainability*, *15*(7), 5769. https://doi.org/10.3390/su15075769

Wider, W., Saad, A., Mahmood, N. A., Ishak, S., Aziz, M. R. A., Wu, C., Wu, H., & Tanucan, J. C. M. (2026). Digital Literacy in Enhancing Collaborative Teaching: A Systematic Review. *The International Review of Research in Open and Distributed Learning*, *27*(1), 210–234. https://doi.org/10.19173/irrodl.v27i1.8717

Wu, D., Sukumaran, S., Zhi, X., Zhou, W., Li, L., & You, H. (2025). Categories, themes and research evolution of the study of digital literacy: a bibliometric analysis. *Education and Information Technologies*, *30*(4), 4907–4931. https://doi.org/10.1007/s10639-024-12955-x

Wu, D., & Zhang, J. (2025). Generative artificial intelligence in secondary education: Applications and effects on students' innovation skills and digital literacy. *PLOS One*, *20*(5), e0323349. https://doi.org/10.1371/journal.pone.0323349

Yang, F., Yao, R., Ren, Y., & Guo, L. (2025). Harmony in diversity: Digital literacy research in a multidisciplinary landscape. *Computers & Education*, *230*, 105265. https://doi.org/10.1016/j.compedu.2025.105265

Zerega, R., Velander, J., & Milrad, M. (2025). Using Emerging Technologies for Bridging Computational Thinking and Artificial Intelligence in Swedish Classrooms: Empirical Insights and Pedagogical Implications. In K. T.E., M. M., & R. I (Eds.), *Lecture Notes in Networks and Systems* (pp. 83–97). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-3-031-84170-5_8