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ARTIFICIAL INTELLIGENCE AND DIGITAL LITERACY IN EDUCATION: A SYSTEMATIC BIBLIOMETRIC REVIEW

INTELIGENCIA ARTIFICIAL Y ALFABETIZACIÓN DIGITAL EN EDUCACIÓN: UNA REVISIÓN BIBLIOMÉTRICA SISTEMÁTICA

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ABSTRACT

Objective: Artificial intelligence (AI) and digital literacy are transforming education by reshaping teaching practices, learning processes, educational quality, and skills development. This study aims to systematically present the developmental landscape of this field. **Methodology:** A bibliometric approach is adopted to review and analyze 183 articles published in the Web of Science Core Collection between 2017 and 2025. This study employs VOSviewer and Scimago Graphica to examine publication patterns, influential research, collaboration networks, and thematic clusters. **Results and Discussion:** The findings indicate that since 2023, both the number of publications and citations have risen sharply, suggesting growing academic attention and increasing scholarly impact. Education-related disciplines remain dominant, while contributions from computer science and other cross-disciplinary fields highlight the interdisciplinary nature of the research. Highly cited papers are mainly focused on applications in higher education, teacher training, healthcare, and agriculture. At the international level, Europe has established extensive collaboration networks. China ranks first in the number of publications, whereas Germany demonstrates strong citation impact. The keyword co-occurrence analysis identifies six clusters, covering technological, pedagogical, ethical, and institutional aspects. The overlay visualization further reveals temporal changes, showing a shift from early research focused on technology and pedagogy to more recent explorations of ethics, governance, and trust. **Conclusions:** Overall, the results confirm that research on AI and digital literacy has accelerated since 2023, with increasing interdisciplinarity and evolving research priorities. **Contribution:** This study outlines the prospects of research on AI and digital literacy and provides important insights into current trends and future directions.
KEY WORDS: Artificial Intelligence; Digital Literacy; Education; Education Quality;

RESUMEN

Objetivo: La inteligencia artificial (IA) y la alfabetización digital están transformando la educación al redefinir las prácticas docentes, los procesos de aprendizaje, la calidad educativa y el desarrollo de habilidades. Este estudio busca presentar sistemáticamente el panorama de desarrollo de este campo. **Metodología:** Se adopta un enfoque bibliométrico para revisar y analizar 183 artículos publicados en la Web of Science Core Collection entre 2017 y 2025. Este estudio emplea VOSviewer y Scimago Graphica para examinar patrones de publicación, investigación influyente, redes de colaboración y grupos temáticos. **Resultados y discusión:** Los hallazgos indican que, desde 2023, tanto el número de publicaciones como el de citas han aumentado considerablemente, lo que sugiere una creciente atención académica y un mayor impacto académico. Las disciplinas relacionadas con la educación siguen siendo dominantes, mientras que las contribuciones de la informática y otros campos interdisciplinarios resaltan la naturaleza interdisciplinaria de la investigación. Los artículos altamente citados se centran principalmente en aplicaciones en la educación superior, la formación del profesorado, la atención médica y la agricultura. A nivel internacional, Europa ha establecido extensas redes de colaboración. China ocupa el primer lugar en número de publicaciones, mientras que Alemania demuestra un fuerte impacto de citas. El análisis de coocurrencia de palabras clave identifica seis grupos, que abarcan aspectos tecnológicos, pedagógicos, éticos e institucionales. La visualización superpuesta revela además cambios temporales, mostrando un cambio desde la investigación temprana centrada en la tecnología y la pedagogía a exploraciones más recientes de la ética, la gobernanza y la confianza. **Conclusiones:** En general, los resultados confirman que la investigación sobre IA y alfabetización digital se ha acelerado desde 2023, con una interdisciplinariedad creciente y prioridades de investigación en evolución. **Contribución:** Este estudio describe las perspectivas de la investigación sobre IA y alfabetización digital y proporciona información importante sobre las tendencias actuales y las direcciones futuras.
PALABRAS CLAVE: Inteligencia artificial; Alfabetización digital; Educación; Calidad educativa;

INTRODUCTION

Artificial intelligence (AI) is rapidly transforming education by reshaping how students learn, how teachers teach, and the skills needed in digital environments (Asad & Anwar, 2025; Grama & Todericiu, 2025; Li et al., 2025; Molina et al., 2025). In parallel, digital literacy has emerged as a core competence, enabling learners

to use technology effectively, evaluate information critically, and apply knowledge across contexts (Zhou et al., 2025). Together, the convergence of AI and digital literacy has become a central topic in educational research, with AI supporting adaptive learning systems, improving assessment, and enabling personalized pathways, while also raising concerns over ethics, governance, and responsibility (Flores-Vivar et al., 2023). Digital literacy is thus essential to ensure that students and educators benefit from AI while addressing these challenges. In recent years, publications and citations in this field have increased significantly, reflecting growing academic and practical interest; however, research remains fragmented, appearing across diverse areas such as healthcare, higher education, teacher training, and agriculture (Castonguay et al., 2023; Cinganotto & Montanucci, 2025; Dimitrijević, 2023; Wang et al., 2023), which makes it difficult to form a coherent and comprehensive perspective on the field.

Therefore, this study systematically organizes research outcomes in the intersecting fields of AI, digital literacy, and education by using visualization tools such as VOSviewer and Scimago Graphica. It aims to clarify the knowledge base, present the developmental trajectory of the research, and highlight newly emerging themes. Guided by these objectives, the study addresses the following research questions (RQs):

1. How have the annual numbers of publications and citations evolved over time in research on AI and digital literacy in education?
2. Which subject categories have played a leading role in shaping this research field?
3. What are the most influential articles in this domain, and what themes do they emphasize?
4. Which countries are the most active in terms of publication output, international collaboration, and citation impact?
5. What thematic clusters emerge from keyword co-occurrence analysis, and how do they reflect the intellectual structure of the field?
6. How have research hotspots shifted over time, and what new directions are suggested by the overlay visualization?

METHODS AND DATA SOURCE

Methods

This study employed a bibliometric method to analyze the selected literature. The aim was to map research trends, identify gaps, and detect emerging themes (Li, 2023; Li, 2025). For visualization, two tools were applied: VOSviewer and Scimago Graphica. VOSviewer is user-friendly and effective in building co-authorship, co-citation, and keyword co-occurrence networks. Thereby revealing intellectual structures and thematic clusters. Scimago Graphica creates interactive visualizations and supports multiple data types. It improves the clarity and interpretability of the results (Chen et al., 2025; Li eta al., 2024; Nag et al., 2025). Using both tools ensured analytical rigorous and facilitated clear presentation.

Data Source

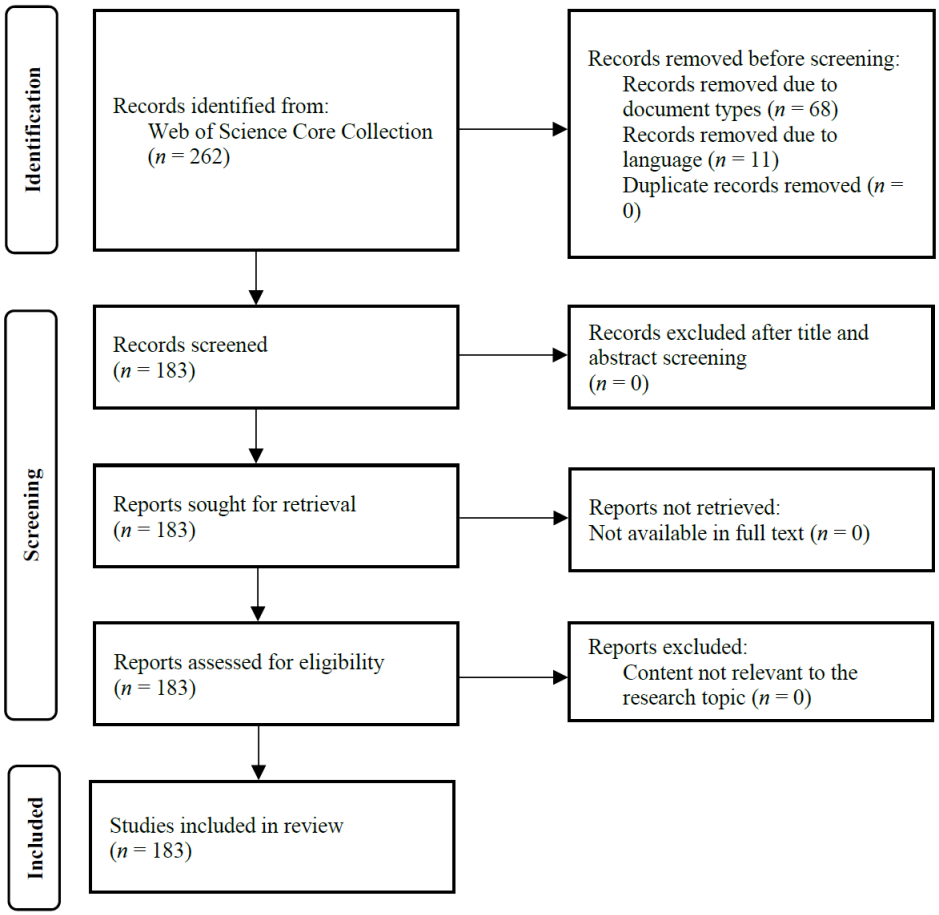
This study initially retrieved 262 publications from the Web of Science Core Collection using the search keywords “AI”, “Digital Literacy” and “Education”. During the identification stage, 79 records were removed prior to screening, including 68 records due to document type restrictions (e.g., proceeding papers, review articles, editorial materials, letters, and meeting abstracts) and 11 records due to language limitations (specifically French and Spanish). No duplicate records were detected. After these exclusions, 183 publications were retained for screening.

In the screening phase, all 183 records were reviewed at the title and abstract level, and none were excluded. Subsequently, all 183 records were available in full text and assessed for eligibility. No records were removed at this stage, as all were deemed relevant to the research topic.

Thus, a total of 183 articles were included in the final sample for bibliometric analysis. This selection process, guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, ensured both methodological rigor and thematic relevance. Figure 1 presents the PRISMA flow diagram,

which illustrates the steps of identification and screening, confirming that all 183 studies were eligible and included in the final analysis.

Figure 1. *PRISMA flow diagram*



RESULTS

Annual Distribution of Publications and Citations

Table 1 presents the annual distribution of publications and citations from 2017 to September 2025. During the initial years (2017–2019), both publication output and citation count remained negligible, with zero publications and citations ranging from 0 to 1. A gradual emergence occurred in 2020 with 3 publications and 6 citations, followed by a modest rise in 2021 and 2022. The year 2023 marked the beginning of a substantial increase, as the number of publications rose to 17 and citations reached 183. This upward trajectory intensified in 2024, with publications increasing to 51 and citations to 605. By 2025 (partial-year data up to September), publication output had more than doubled to 104, while citations escalated to 972. The synchronous growth in publications and citations highlights both the rapid expansion of research activity and the growing scholarly impact of the field over the past three years.

Table 1. *Annual Distribution of Publications and Citations (2017-2025.9)*

Years	Number of Publications	Number of Citations
2017	0	1
2018	0	0
2019	0	0
2020	3	6
2021	5	60
2022	3	126
2023	17	183
2024	51	605
2025	104	972

Leading Categories of the Study

Table 2 presents the top 10 Web of Science categories represented among the 183 selected records. The dominant category is Education Educational Research, which accounts for 81 records, representing 44.26% of the total. The second largest category, Education Scientific Disciplines, contains 14 records (7.65%), followed by Information Science Library Science with 10 records (5.46%). Several categories contribute between 8 and 7 records each, including Computer Science Information Systems (4.37%), Environmental Sciences (4.37%), Engineering Multidisciplinary (3.83%), Environmental Studies (3.83%), and Green Sustainable Science Technology (3.83%). Finally, both Computer Science Interdisciplinary Applications and Linguistics contribute 6 records each (around 3.3%). The distribution reveals a clear dominance of education-related categories, complemented by meaningful contributions from computer science, environmental sciences, and interdisciplinary fields.

Table 2. *Top 10 Categories of the Study*

Rank	Web of Science Categories	Record Count	% of 183
1	Education Educational Research	81	44.26
2	Education Scientific Disciplines	14	7.65
3	Information Science Library Science	10	5.464
4	Computer Science Information Systems	8	4.37
5	Environmental Sciences	8	4.372
6	Engineering Multidisciplinary	7	3.825
7	Environmental Studies	7	3.825
8	Green Sustainable Science Technology	7	3.825
9	Computer Science Interdisciplinary Applications	6	3.28
10	Linguistics	6	3.279

Leading Cited Articles

Table 3 lists the ten most cited papers in the dataset, reflecting the central research directions and interdisciplinary scope at the intersection of AI, education, and digital literacy. The most cited article is AI in Dentistry: Chances and Challenges by Schwendicke et al. (2020). It has 524 citations. It reviews applications

of AI in dentistry. It emphasizes rigorous methods, ethical responsibility, and the importance of digital literacy in clinical practice. The second article is by Chiu et al. (2024). It has 221 citations. The study reports evidence from K–12 education. It shows that teacher support and student motivation are important in AI-based learning. Machleid et al. (2020) is cited 110 times. The authors use a mixed-methods design. They examine European medical students' views of digital health education. It finds a gap between current curricula and the digital skills needed in healthcare. Other influential works include Flores-Vivar et al. (2023). This article discusses ethical challenges of AI in education under the SDG4 framework. Another is Wang et al. (2023). It uses PLS-SEM analysis to show that universities' AI capacities improve students' creativity, self-efficacy, and learning performance. Further notable works extend to nursing education (Castonguay et al., 2023), the structural challenges of generative AI in higher education (Walczak & Cellary, 2023), digital proficiency of nursing students (Abou Hashish & Alnajjar, 2024), teacher education (Zhang & Zhang, 2024), and agricultural transformation in developing countries (Kitole et al., 2024). Collectively, these top-cited studies highlight the interdisciplinary impact of AI research across healthcare, higher education, pedagogy, and agriculture.

Overall, the dataset includes 183 publications with a total of 1,955 citations, averaging 10.68 citations per paper and an h-index of 19. These bibliometric indicators reveal that while a few seminal works account for a disproportionate share of citations, the broader body of literature demonstrates consistent scholarly engagement across multiple fields. Together, the citation metrics and the top-cited articles underscore both the growing significance and the interdisciplinary relevance of AI, education, and digital literacy research in addressing contemporary societal challenges.

Table 3. *Top 10 cited articles*

Rank	Author(s)	Title	Source Title	Total Citations
1	Schwendicke et al. (2020)	AI in Dentistry: Chances and Challenges	Journal of Dental Research	524
2	Chiu et al. (2024)	Teacher support and student motivation to learn with AI based chatbot	Interactive Learning Environments	221
3	Machleid et al. (2020)	Perceptions of Digital Health Education Among European Medical Students: Mixed Methods Survey	Journal of Medical Internet Research	110
4	Flores-Vivar et al. (2023)	Reflections on the ethics, potential, and challenges of AI in the framework of quality education (SDG4)	Comunicar: Media Education Research Journal	99
5	Wang et al. (2023)	Effects of higher education institutes' AI capability on students' self-efficacy, creativity and learning performance	Education and Information Technologies	88

6	Castonguay et al. (2023)	Revolutionizing nursing education through Ai integration: A reflection on the disruptive impact of ChatGPT	Nurse Education Today	71
7	Walczak & Cellary (2023)	Challenges for higher education in the era of widespread access to Generative AI	Economics and Business Review	46
8	Abou Hashish & Alnajjar (2024)	Digital proficiency: assessing knowledge, attitudes, and skills in digital transformation, health literacy, and AI among university nursing students	BMC Medical Education	40
9	Zhang & Zhang (2024)	AI in teacher education: Unlocking new dimensions in teaching support, inclusive learning, and digital literacy	Journal of Computer Assisted Learning	40
10	Kitole et al. (2024)	Digitalization and agricultural transformation in developing countries: Empirical evidence from Tanzania agriculture sector	Smart Agricultural Technology	35

Country-Level Research Performance

Table 4 and Figure 2 present the top countries by total link strength in the collaboration network. Although the initial intention was to identify the top 10 countries, five nations share the same score at the lower end of the ranking. As a result, 13 countries are reported in total. Italy ranks first with a total link strength of 23, followed closely by Germany with 22 and Spain with 21. Austria and the United Kingdom both record a score of 20, indicating comparable levels of collaboration. China records 14, while Hungary and the Netherlands each record 13. The remaining countries such as Albania, Greece, Portugal, Slovenia, and Switzerland, share the same score of 11, reflecting a tie at the 10^{th} place.This distribution reveals that European countries, particularly Italy, Germany, Spain, Austria, and the United Kingdom, are highly central in international research collaborations. China also demonstrates a notable role outside Europe, highlighting the participation of Asian research communities. The global map further illustrates that strong collaborative networks are concentrated in Europe, with moderate engagement in Asia, while other regions such as Africa and South America show relatively limited involvement in the research network.

Table 4. *Top 13 Countries by Total Link Strength in the Collaboration Network*

Rank	Countries	Total Link Strength
1	Italy	23
2	Germany	22
3	Spain	21
4	Austria	20
5	United Kingdom	20
6	China	14
7	Hungary	13
8	Netherlands	13
9	Albania	11
10	Greece	11
11	Portugal	11
12	Slovenia	11
13	Switzerland	11

Figure 2. *Global Distribution of Countries by Total Link*

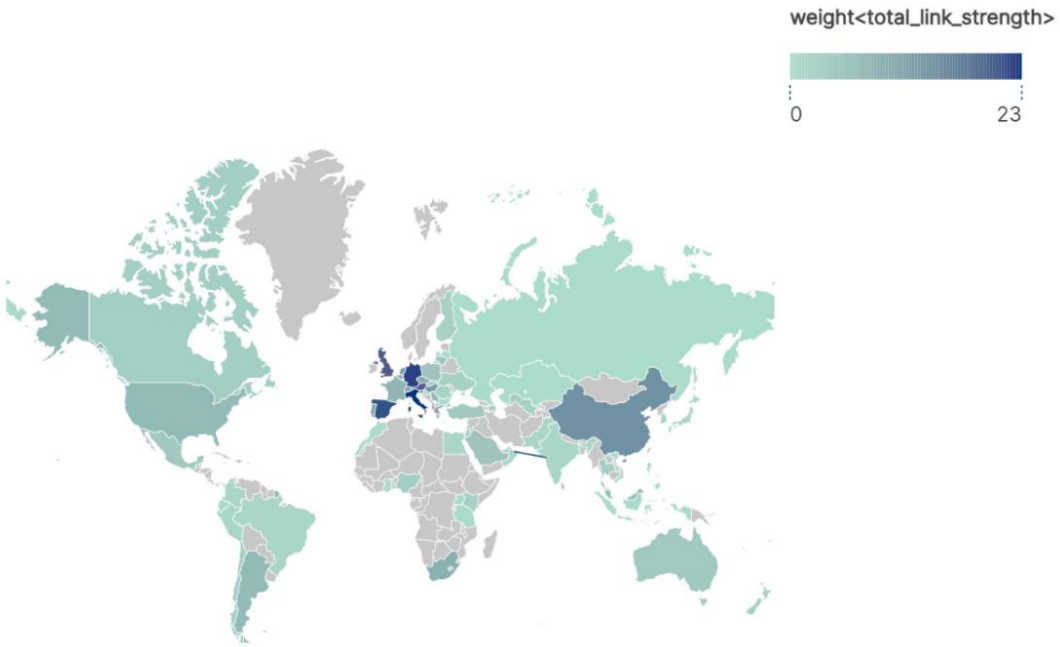


Table 5 and Figure 3 illustrate the distribution of publications by country based on document count. China ranks first with 32 publications, followed by the United States with 19 and Spain with 16. The United Kingdom holds fourth place with 12 publications, while Germany contributes 10. Saudi Arabia contributes 9 and Ukraine contributes 8, also appearing among the leading contributors. Malaysia, Australia, Turkey, and India each produce 7 publications, resulting in a total of 11 countries being listed in the ranking.

This distribution highlights China's clear leadership in publication volume, followed by substantial contributions from major research economies such as the United States, Spain, and the United Kingdom. The presence of emerging contributors, including Saudi Arabia, Malaysia, and Turkey, further demonstrates the growing global engagement in this research domain. The global map reveals strong concentrations of research activity in Asia, North America, and parts of Europe, while regions such as Africa and South America remain underrepresented in terms of publication output.

Table 5. *Top 11 Countries by Document Count*

Rank	Countries	Document Count
1	China	32
2	USA	19
3	Spain	16
4	United Kingdom	12
5	Germany	10
6	Saudi Arabia	9
7	Ukraine	8
8	Malaysia	7
9	Australia	7
10	Turkey	7
11	India	7

Figure 3. *Global Distribution of Countries by Document Count*

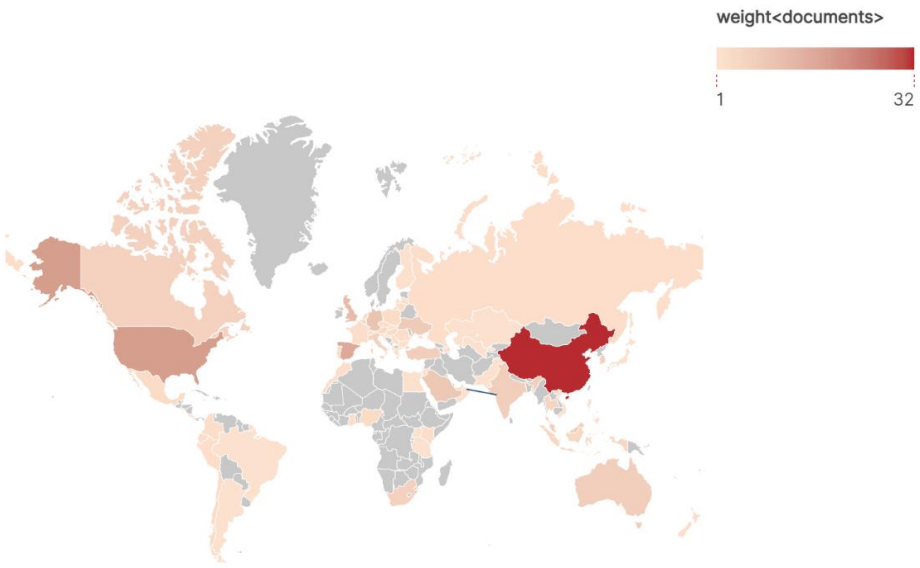


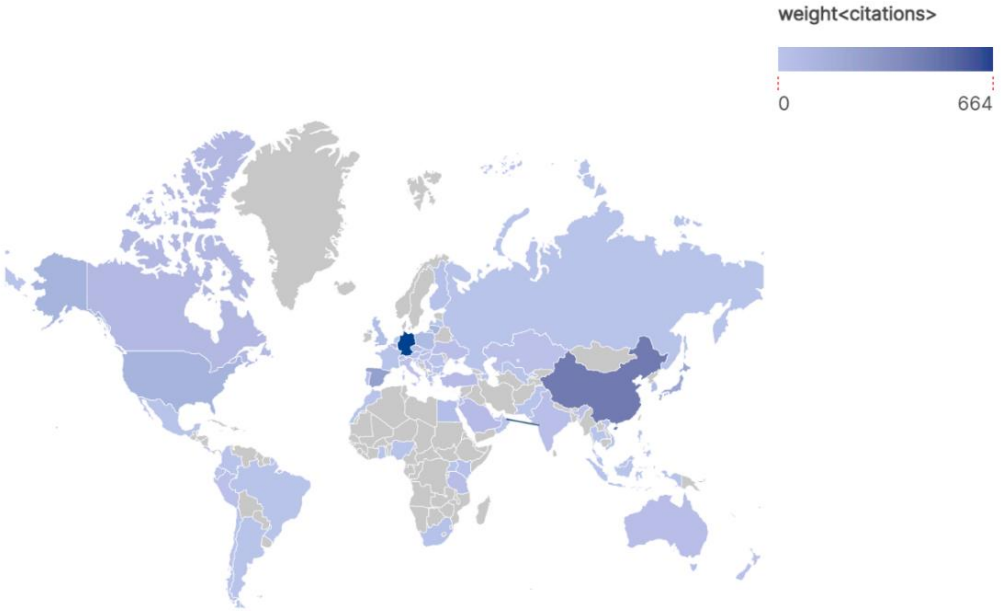
Table 6 and Figure 4 present the top 10 countries ranked by citation count within the collaboration network. Germany leads with 664 citations, hilighting its dominant role in research influence. China follows with 458 citations, while Spain ranks third with 263. Japan holds the fourth position with 221, ahead of the United States with 123 citations. Belgium records 122 citations, closely followed by Lithuania with 110. Canada contributes 79 citations, while Poland and the United Kingdom complete the top 10 with 69 and 58 citations, respectively.

This distribution highlights Germany's central role in terms of citation impact, with China also emerging as a major research hub. Spain and Japan further strengthen the representation of European and Asian research communities, while the presence of countries such as Belgium and Lithuania underscores the role of smaller European nations in the citation landscape. The global map illustrates that high citation counts are concentrated in Europe and Asia, with more moderate levels in North America, whereas regions such as Africa and South America remain notably underrepresented in terms of scholarly impact.

Table 6. Top 10 Countries by Citation Count in the Collaboration Network

Rank	Countries	Citation Count
1	Germany	664
2	China	458
3	Spain	263
4	Japan	221
5	USA	123
6	Belgium	122
7	Lithuania	110
8	Canada	79
9	Poland	69
10	United Kingdom	58

Figure 4. Global Distribution of Countries by Citation Count



Keyword Co-occurrence Network Analysis

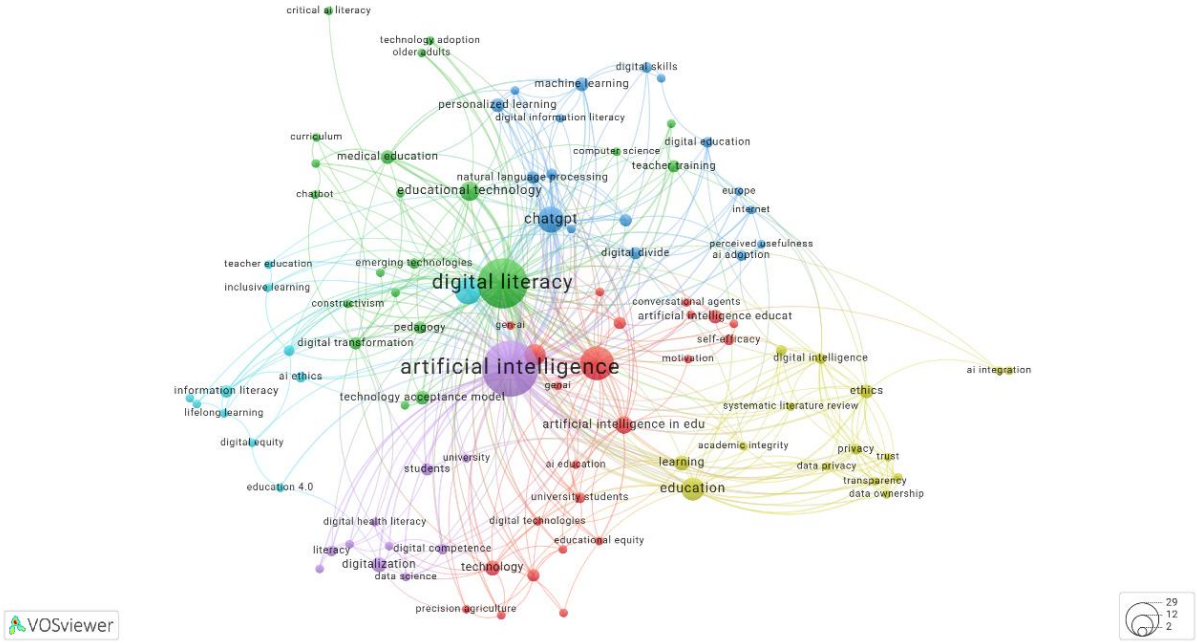
In this section, a co-occurrence analysis of research keywords was conducted. The aim was to capture the intellectual landscape of studies on AI and digital literacy in education. A total of 649 keywords were identified from the dataset. After applying a minimum occurrence threshold of two, 98 keywords were retained for analysis. All of these keywords were included in a single connected component. This component was used for visualization to improve clarity and interpretability. The final network contained 445 links with a total link strength of 709. The keywords were distributed across six clusters. Each cluster represents a thematic dimension of research in this field, as shown in Figure 5.

The red cluster centers on “AI”, connected with terms such as “learning”, “students”, and “education”. Studies here discuss how technologies reshape classroom practice and enhance engagement, while considering how traditional settings adjust to new methods.The green cluster highlights digital literacy and educational technology. With keywords like “teacher education” and “curriculum”, it focuses on integrating innovative tools into course design. Inclusivity and interactive resources are also stressed as ways to build more flexible

learning environments.The blue cluster is concerned with digital competences. Core terms include “machine learning”, “digital skills”, “digital education”, and “information literacy”. Research emphasizes the need to strengthen skills for managing digital information, pointing to their relevance for lifelong learning.The yellow cluster turns to governance, ethics, and accountability. Representative terms are “ethics”, “privacy”, “trust”, and “systematic literature review”. Rather than technology alone, these studies raise issues of fairness and responsibility, often touching on data ownership, user trust, and transparency. They underline the need for clear ethical frameworks.The purple cluster relates to systemic and institutional change, with “digital competence”, “technology”, and “digital health literacy” as key terms. It highlights links between innovation and organizational reform, showing how competence frameworks help schools and universities align digital strategies with broader goals.Finally, the light blue cluster reflects emerging themes. Keywords such as “ChatGPT”, “personalized learning”, and “digital transformation” signal growing interest in conversational technologies that support student-centered learning and indicate the expanding role of generative tools in education.

The six clusters collectively demonstrate how research on AI and digital literacy education extends beyond classroom practices and digital skills to encompass broader issues of ethics, governance, and institutional transformation. They also point toward emerging themes such as generative technologies.

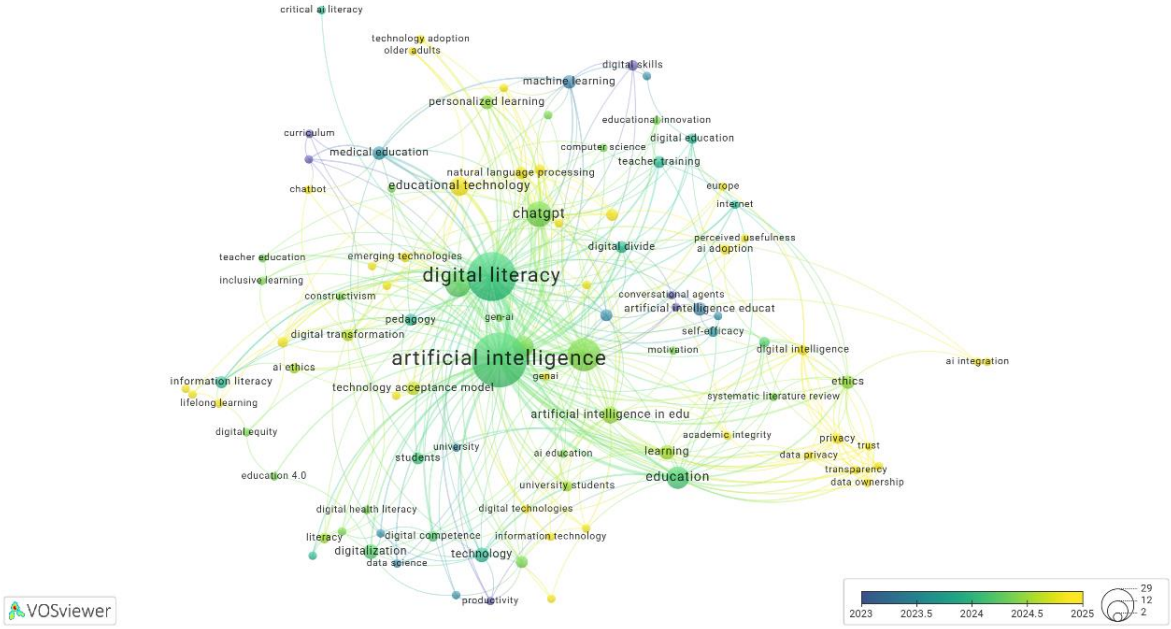
Figure 5. Keyword Co-Occurrence Network Visualization



Keyword Co-Occurrence Overlay

Figure 6 shows an overlay visualization of keyword co-occurrence by average publication year. Each node has a color that shows the year. Blue means the study is older. Yellow means the topic is newer. “AI” and “digital literacy” are in green to light yellow. This shows that both are still active and important in recent years. In contrast, keywords such as “AI integration”, “privacy”, “trust” and “data ownership” are marked in yellow, reflecting their emergence since 2024. Meanwhile, terms like “machine learning” and “educational innovation” appear in blue, signifying earlier research themes. Overall, the figure highlights both the enduring core themes in this field and the temporal evolution of research hotspots, showing a clear shift from traditional applications to issues of ethics, governance, and trust.

Figure 6. Keyword Co-Occurrence Overlay



CONCLUSIONS

This study provides a systematic bibliometric review of 183 articles on AI and digital literacy in education. By applying bibliometric and visualization techniques, the findings address six key research questions.

First, the analysis of annual publications and citations shows that research in this field has grown rapidly in recent years, with a sharp increase beginning in 2023. This trend reflects both the rising academic interest and growing influence of AI and digital literacy studies in education. Particularly noteworthy is that this rapid growth is driven by the emergence of new technologies, the accelerated adoption of generative AI, and policy discussions surrounding digital skills and educational innovation.

Second, subject category analysis indicates that education-related disciplines dominate this research area, particularly educational research and education-related scientific disciplines. However, contributions from computer science, environmental sciences, and interdisciplinary fields also highlight the inherently cross-disciplinary nature of the topic. The involvement of computer science reflects the technological foundations of AI. The participation of environmental science demonstrates that digital literacy and AI applications are increasingly linked to sustainable development and societal challenges. This multidisciplinary collaboration highlights the field's interdisciplinary nature, indicating that research on AI and digital literacy profoundly impacts not only educational theory and practice but also broader societal, technological, and policy dimensions.

Third, citation analysis identifies a set of highly influential articles that span healthcare, higher education, pedagogy, and agriculture. These works demonstrate the interdisciplinary applications of AI and digital literacy, emphasizing methodological rigor, ethical responsibility, and the cultivation of digital competences. Across these fields, highly cited papers consistently emphasize methodological rigor, ethical responsibility, and the cultivation of digital competencies. Collectively, they demonstrate that AI and digital literacy are not only becoming essential foundations for professional practice but are also driving broader transformations in education and society.

Fourth, country-level analysis reveals strong contributions from Europe and Asia. Italy, Germany, and Spain are central in collaboration networks, while China and the United States stand out in publication volume.

Germany and China also play leading roles in terms of citation impact, showing that both matured and emerging research economies are actively shaping the field.

Fifth, keyword co-occurrence analysis highlights six thematic clusters: AI in education, digital literacy and technology integration, digital competences, governance and ethics, institutional transformation, and emerging conversational technologies. Collectively, these clusters reflect the intellectual structure of the field, combining technological, pedagogical, ethical, and institutional perspectives.

Finally, the overlay visualization shows the shifting trajectory of research hotspots over time. Earlier studies emphasized technical and pedagogical aspects, while recent work increasingly addresses ethics, governance, and user trust. The emergence of generative AI and tools such as ChatGPT highlights future directions, pointing to both opportunities and challenges for education.

In summary, this study maps the rapid development, disciplinary foundations, influential works, geographical patterns, thematic clusters, and temporal shifts of research on AI and digital literacy in education. These findings provide a comprehensive overview of the field, offering guidance for future research and practical applications.

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