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Mapping Research on Artificial Intelligence in Education: A Bibliometric Analysis

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Abstract: This research aims to explore the development of academic publications on artificial intelligence (AI) in education. Using bibliometric analysis, this research examines scientific publications indexed in Scopus from 2020 to 2024. The primary keyword utilized for data collection is "artificial intelligence in education." The analysis reveals a significant increase in publications featuring this keyword during the specified period. Europe emerged as the leading region in AI-related educational research, with the Netherlands contributing the most scientific publications on this topic. Notably, Ismaila Temitayo Sanusi was identified as the most prolific researcher, while Davy Tsz Kit Ng recorded the highest number of citations. Among publication venues, the journal Computers and Education: Artificial Intelligence was identified as the platform with the largest volume of publications on this subject. These findings underscore the growing academic interest in AI in the education sector. Furthermore, this research highlights opportunities for further exploration in less-studied areas, such as AI education, AI literacy, curriculum design, and the impact of AI on learning outcomes. These gaps highlight the necessity for further research on effectively integrating AI to improve global educational practices.

Keywords: *artificial intelligence; bibliometric research; education*

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INTRODUCTION

Artificial intelligence (AI) technology has profoundly influenced numerous facets of human existence, not least within the educational sector (Abichandani et al., 2023; Alfredo et al., 2024). Over the past few years, AI applications in the education sector have become increasingly widespread, including in education system management, student performance evaluation, and data-based learning personalization (Leiker et al., 2023; Sunarto et al., 2024). AI offers innovative solutions to enhance the effectiveness of the learning process, such as the development of virtual tutors, learning analytics, and predictive modeling to monitor student performance in real time (Moya & Camacho, 2024). With these technological advances, there is an urgent need to understand how AI is implemented, the challenges it poses, and the potential it offers for optimization in an educational context (Hossen & Uddin, 2023; Rejeb et al., 2024). One effective way to understand trends and directions in AI in education research is through bibliometric analysis, which enables the identification of publication patterns, research collaborations, and dominant research topics.

However, despite the rapid growth of academic research on AI in education, several issues warrant further investigation. First, although many studies have analyzed the positive impacts of AI technologies implementation in education, a significant gap persists in comprehending the long-term effects of AI on both traditional and innovative teaching methods (Martinez-Moreno & Petko, 2024). Second, previous studies have often focused solely on specific regions or technologies, resulting in limited research that includes global or longitudinal analyses of AI trends in education over an extended period (Ma et al., 2024). Based on the literature review, previous studies, such as those by Hwang et al. (2020) and Minn (2022), have examined the application of AI in adaptive learning, but there has been little comprehensive mapping of publication trends and global collaboration. Additionally, most studies are exploratory and do not employ a comprehensive quantitative approach to map emerging topics.

This study aims to map research on Artificial Intelligence in educational contexts during the period 2020 to 2024, using bibliometric analysis methods (Donthu et al., 2021; Klarin, 2024). Through this approach, this study goes beyond merely outlining prevailing research trends to identify research gaps, potential collaborations among researchers, and the most studied topics during the period. It is hypothesized that this investigation will contribute meaningfully to the development of future research strategies and encourage further innovation in the application of AI in education (Almatrafi et al., 2024; Martinez-Moreno & Petko, 2024). The contribution of this research includes enhancing the understanding of how AI has impacted and can continue to influence the learning process (Lee et al., 2024; Rodway & Schepman, 2023; Solihat et al., 2024) and establishing a basis for future research that focuses more on the development of AI-based educational technology.

The objective of this research is to delineate the research framework established between 2020 and 2024. The research roadmap is essential for guiding future research (Anderson, 2014; Daoutidis et al., 2018;

Gianotti & Giudice, 2020). The display of scholarly results findings offers insight into the thematic developments of studies conducted between 2020 and 2024, as well as the key stakeholders involved in AI-related educational research. Specifically, this study highlights: 1) the countries and academic institutions that have significantly contributed to the scholarly literature on AI in education; 2) the academic journals that frequently publish articles on this topic; 3) the recurring themes identified in AI-focused educational literature; and (4) researcher data reflecting significant scholarly engagement with AI in the educational context.

METHODS

This research employs bibliometric analysis to examine data derived from academic journal articles. It aims to elucidate the patterns, trends, and metadata associated with scholarly publications that focus on employing AI in educational contexts. Furthermore, this study uses the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The PRISMA model is a guiding framework that ensures transparency, systematicity, and completeness in reporting the results of systematic reviews and meta-analyses (Page et al., 2021; Yepes-Nuñez et al., 2021). We use the PRISMA model to illustrate the processes of identification, selection, and screening of articles published in academic journals.

The search for articles themed "Artificial Intelligence in Education" was conducted in journals indexed in Scopus for the period from 2020 to 2024. Because we want to see the development of AI research in education after the COVID-19 pandemic, which was first discovered in 2019, we focused the research on the period 2020 to 2024. The keywords "Artificial Intelligence" and "Education" were used to select articles relevant to the research focus. We also used alternative keywords, including "AI in education," to increase the efficiency and coverage of search results and ensure a more focused, comprehensive search. Journals indexed in Scopus were selected for their rigorous peer-review process, which ensures that published articles meet high academic standards and contribute significantly to their respective fields (Caputo & Kargina, 2022).

Furthermore, Scopus provides extensive metadata, including author analysis, institutional affiliations, and country coverage, allowing for a more thorough examination of the research landscape. By focusing on articles published between 2020 and 2024, the research encompasses the most recent advancements and trends in the implementation of Artificial Intelligence in educational contexts, offering meaningful insights into the current state of the field. The use of Scopus as the primary database, combined with targeted keywords and a time frame, ensures that the selected articles are high-quality, relevant to the research goals, and representative of the current state of AI in Education research.

This research study exclusively included peer-reviewed articles, thereby ensuring a high standard of quality and academic rigor (Huisman & Smits, 2017). Articles that had not been subjected to peer review were deliberately excluded from the analysis to maintain the reliability and validity of the research findings. The decision to use only peer-reviewed articles was grounded in the need for credible, authoritative sources that contribute meaningfully to the prevailing research findings. The criteria for classifying articles as peer-reviewed require that they have undergone a formal editorial review process, including correspondence with the editor, receipt of proof of review, and documented communication between the authors and the editorial team. By adhering to these established criteria, the study aimed to enhance the integrity of its findings. In total, 181 articles were independently selected for a bibliometric analysis, reflecting a comprehensive, methodologically sound approach to exploring the literature on AI in Education.

This research encompasses a series of meticulously executed procedures aimed at exploring the theme of AI in Education. Initially, we established the primary research theme, which serves as the focal point of our analysis. Following this identification, we selected Scopus as the primary database for sourcing relevant articles aligned with the objectives of our study. To facilitate our search, we employed the keywords "Artificial Intelligence" and "education," ensuring a targeted approach to gather pertinent literature.

After identifying articles that had successfully undergone peer review and were available as open access, we exported this selection into both RIS (Research Information System) and Microsoft Excel formats for further analysis. This dual-format export provides greater flexibility for data manipulation and organization. Subsequently, the collected data were processed using VOSviewer, a specialized tool for visualizing bibliometric networks. By utilizing VOSviewer, we aimed to generate comprehensive visual representations that illustrate the relationships and trends within the literature on AI in Education. This structured method deepens comprehension of the available research literature while also enabling the recognition of prominent scholars and emerging topics in this fast-developing domain

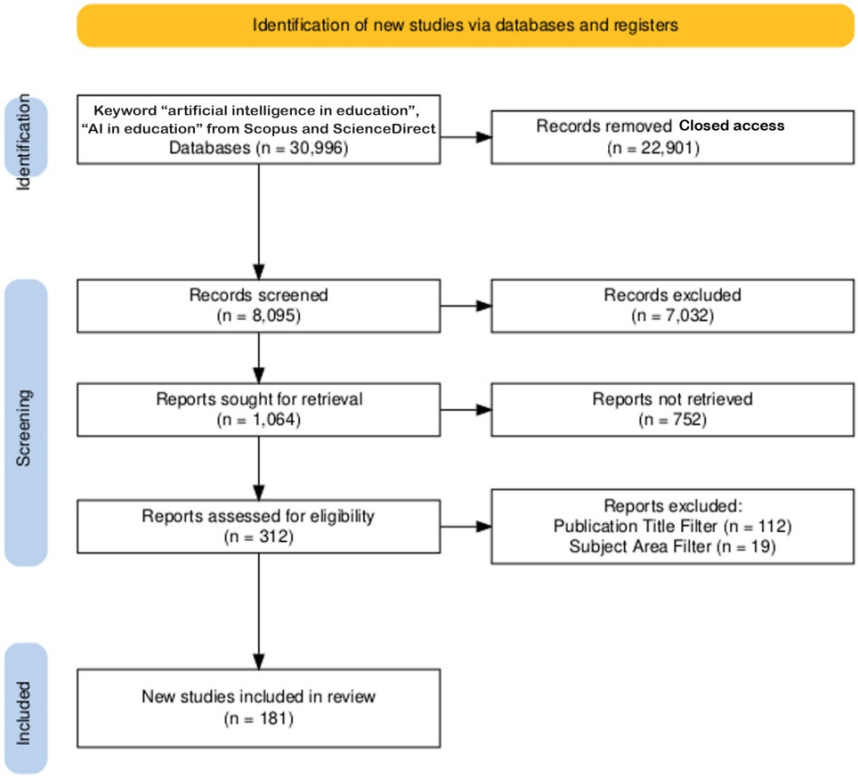

Figure 1. PRISMA on Artificial Intelligence in Education Publication

Figure 1 illustrates the article selection procedure based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram. The stages involved are as follows:

At this stage, relevant literature was identified through keyword searches for "artificial intelligence in education" and "AI in education" in the Scopus database using the Harzing Publish or Perish application and ScienceDirect. The process generated 30,996 relevant publications. However, 22,901 articles were excluded due to restricted access (closed access), leaving 8,095 articles for further screening.

During the screening stage, out of the remaining 8,095 articles, 7,032 articles that failed to meet the predefined relevance criteria were excluded from the analysis based on their abstracts or titles. Consequently, 1,064 articles proceeded to the next stage for full-text retrieval. Of the 1,064 articles requested for full-text retrieval, 752 could not be accessed or retrieved for various reasons (e.g., document unavailability). Subsequently, the 312 successfully retrieved articles were further evaluated for eligibility. In this assessment, 112 articles were excluded as irrelevant based on their publication titles, and 19 were excluded for not aligning with the predetermined subject areas.

A total of 181 articles, fully compliant with the established criteria, were included in the concluding stage of the systematic review. These articles were considered relevant for further analysis within the context of the study. This procedure ensures that the article selection process is systematic and transparent, with strict adherence to inclusion and exclusion criteria to obtain valid and reliable results. The bibliometric analysis conducted in this study used VOSviewer version 1.6.20, a powerful software tool specifically designed to visualize bibliometric networks (Bukar et al., 2023; Kirby, 2023; van Eck & Waltman, 2010). This application generates detailed bibliometric maps that facilitate a comprehensive interpretation of the patterns and interconnections identified across the reviewed literature. The results produced by VOSviewer can be presented in various formats, including images, tables, and graphs, facilitating an in-depth examination from multiple analytical perspectives.

The data collected from Scopus-indexed journals was meticulously exported in both RIS *(Research Information System)* format and Microsoft Excel to ensure compatibility with the visualization software. This dual-format approach enables greater flexibility in data manipulation and organization. Following this, the RIS data and the Excel spreadsheet were systematically used to create visualizations in VOSviewer, which illustrate key patterns, such as citation networks, co-authorship relationships, and thematic clusters, related to the study of AI in educational environments. The research process undertaken in this study can be systematically represented in the following flowchart, which outlines each stage in a structured, sequential manner.

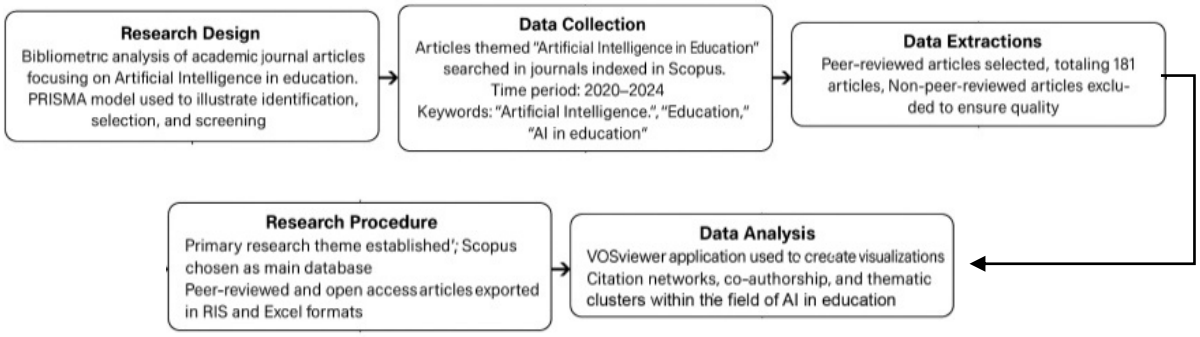

Figure 2. Research Flowchart

RESULT AND DISCUSSION

The development of technology worldwide is growing rapidly, including Artificial Intelligence (AI) (Liu et al., 2021; Marino et al., 2023). Through various research studies, scholars have uncovered numerous insights regarding the capabilities and implications of AI technology. The growing awareness among researchers of the importance of technology integration in the education sector has led to a notable increase in the publication of scholarly articles in academic journals. This trend reflects a growing commitment to exploring how AI can enhance educational practices and outcomes.

Consistent with the study's objectives, the findings are herein reported and graphically illustrated through the provided tables and figures. Figure 3, derived from the Scopus database, depicts the annual increase in publications about AI in education over the years. The data presented in this figure highlight a significant upward trajectory in the volume of publications over the last five years, indicating that interest in this field is steadily increasing. This surge in scholarly output underscores the relevance of AI in educational contexts and the importance of sustained research efforts to fully understand and leverage AI technologies to improve teaching and learning experiences.

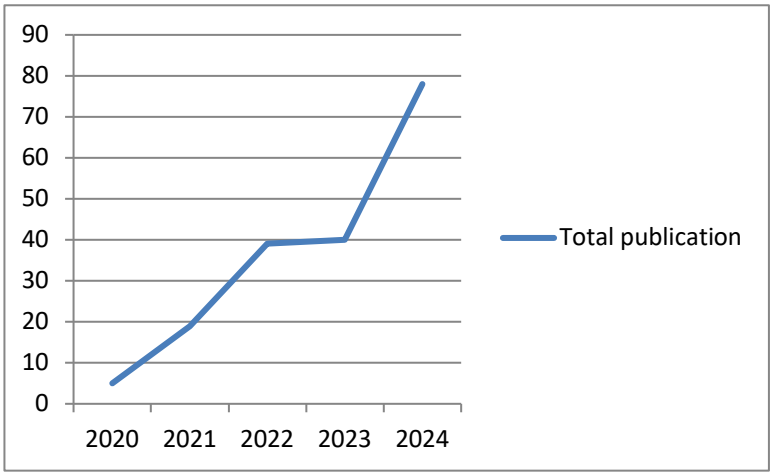

Figure 3. Published data from 2020 to 2024

Table 1 presents a ranking of the top three countries that have made significant contributions to the publication of articles in journals indexed by Scopus focusing on AI in educational contexts. This data reflects the prominence of these nations in advancing research and discourse within this domain. By identifying the leading countries, the table provides valuable insights into the global distribution of scholarly output related to AI applications in educational contexts. The information presented serves as an important indicator of the countries at the forefront of exploring the transformative possibilities enabled by AI solutions to enhance pedagogical activities and practices worldwide.

Table 1. The leading three countries in publications related to artificial intelligence in education

Country	Total Publication
Netherland	114
United Kingdom	43
Australia	24

As shown in Table 1, the Netherlands is the leading contributor to the publication of articles on Artificial Intelligence in Education in Scopus-indexed journals. This prominence highlights the country's commitment to advancing research in this critical area. Recent studies in this domain have primarily focused on adapting AI technologies to enhance learning processes and outcomes. Researchers are exploring innovative applications of AI to improve educational practices, thereby fostering a more effective and personalized learning environment for students across various educational settings (Berkat, 2024; Bhutoria, 2022; Martin-Nunez et al., 2023).

Unfortunately, the significant contribution of European research is not balanced with that of other continents. Although Asia and America have significant potential for technological development, the number of publications from these regions is still lagging behind Europe. Differences could influence this in research funding allocation, government policies, the readiness of technology-based education infrastructure, and the need for technological innovation to support distance learning and online teaching. As shown in Table 2, a range of academic journals have played a pivotal role in advancing the scholarly discourse surrounding Artificial Intelligence in Education by consistently publishing high-quality, peer-reviewed articles that explore its implementation, challenges, and potential benefits in educational contexts.

Table 2. Top Six Journals by Total Publication

Journal	Total Publication
Computers and Education: Artificial Intelligence	106
Computers & Education	26
Computers & Education Open	24
The International Journal of Management Education	10
Thinking Skills and Creativity	8
International Journal of Educational Research	7

As shown in Table 2, Scholarly publications on Artificial Intelligence in Education are primarily published in journals spanning the social sciences and technology. This interdisciplinary representation underscores the multifaceted nature of research in this domain, which encompasses pedagogical, cognitive, and technological aspects (Luckin & Holmes, 2016). A total of 181 research publications were issued in journals across the fields of social sciences and technology, specifically focusing on education and computer science, highlighting the interdisciplinary nature of research in these domains.

Research publications on "Artificial Intelligence in Education" predominantly appear in journals that specialize in technology and education, such as *Computers and Education: Artificial Intelligence* and *Computers & Education*. In contrast, journals with a primary focus on pedagogy and education are less likely to feature studies on AI. This disparity highlights a divergence in the distribution of research focus regarding AI in education. Technology-oriented journals tend to be more receptive to exploring digital innovations, involving the implementation of AI to support and optimize learning, the development of adaptive learning systems, and learning analytics. These journals offer a broad platform for technical discussions on how technologies, particularly AI, can drive educational transformation across various levels. On the other hand, pedagogy and education-focused journals seem to have yet to make AI a central area of interest. This opens opportunities for broader interdisciplinary collaboration to bridge the divide between technological innovation and pedagogical development.

The bibliometric analysis presents data on prominent researchers who have made significant contributions to the publication of works related to Artificial Intelligence in Education. These leading researchers are identified based on their publication output and their accumulated citations in scholarly literature. Table 3 presents the publication counts and citation metrics for these notable scholars working on Artificial Intelligence in educational contexts.

Table 3. The Top Nine Authors Contributing to The Artificial Intelligence in Education Publication

Author	Total Publication	Total Citation
Ismaila Temitayo Sanusi	6	448
Thomas K.F. Chiu	3	91
Albert C.M. Yang	2	77
Cathrine E. TA	2	5
Davy Tsz Kit Ng	2	731
Eduard Pogorskiy	2	21
Pablo Bautista	2	22
Pieta Sikstrom	2	55
Venkat Srinivasan	2	70

Table 3 presents a ranking of leading researchers based on their total number of publications and citations within the field of Artificial Intelligence in Education. Notably, the correlation between publication counts and citation counts is not always consistent. For instance, Ismaila Temitayo Sanusi has six publications, yet the highest citation count belongs to Davy Tsz Kit Ng, who has only two publications. This discrepancy can be attributed to several factors, including the quality of the articles and the reputation of the journals in which they appear. High-quality research published in well-regarded journals tends to receive more citations, influencing the overall citation metrics of individual authors within the academic community. The most cited articles often address critical themes such as AI literacy, which is essential for achieving educational goals through the effective use of AI technologies. The insights presented in Table 3 not only highlight individual contributions but also provide opportunities for collaborative research with prominent scholars in the field. Engaging with these leading researchers could foster innovative projects that advance our understanding of AI applications in education, ultimately enhancing educational practices and outcomes for learners across diverse contexts.

A co-citation analysis was conducted with cited authors serving as the unit of analysis. This approach allowed us to examine the relationships and citation patterns among various authors within the field, providing insights into the influence and interconnectedness of their works (Lim & Buntine, 2016). Figure 4 displays the structure of citation interactions among influential authors in the field of Artificial Intelligence in Education. Among these notable scholars, Roberto Martinez-Maldonado stands out as a significant figure whose work has been extensively referenced by other researchers, serving as a foundational basis for their research. He is recognized as an author of influential books and articles, frequently used in educational contexts, particularly on AI in Education. His popular works cover research domains including Artificial Intelligence in Education, Human-Centered AI, Learning Analytics, and Collaborative Learning, following the work of Maldonado, Simon Knight, and Dragan Gasevic, whose writings are often referenced by many researchers to guide the direction of their studies. Simon Knight and Dragan Gasevic's articles focus on Learning Analytics, Learning Technologies, Philosophy of Education, and Learning Science.

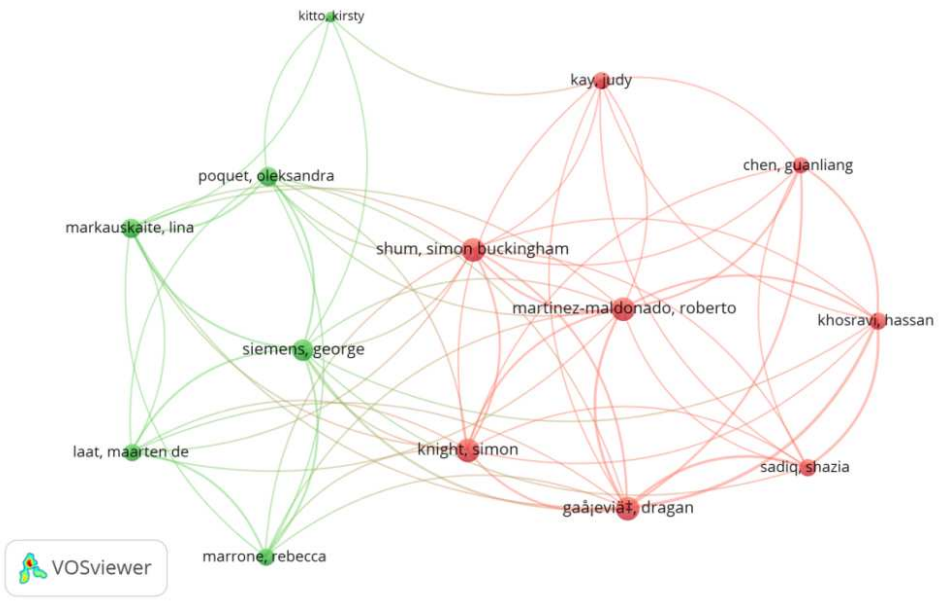

Figure 4. Co-citation analysis of referenced authors

The analysis of recent publication trends in AI in Education over the last five years has identified a diverse set of keywords, indicating the field's continual development and shifting research priorities. These publication trends serve as a foundation for ongoing research while simultaneously guiding future publication directions in this rapidly advancing domain. The findings from this analysis indicate the emergence of new research avenues and publication opportunities, underscoring the field's dynamic and multifaceted nature.

Figure 4 illustrates the key keywords associated with research on Artificial Intelligence in Education, offering valuable insights into the thematic focus of recent publications. The visual representation highlights the interconnectedness of various concepts, such as learning analytics, adaptive learning, and educational technology, demonstrating the interdisciplinary nature of AI applications in education. By examining these keyword trends, researchers can identify potential areas for collaboration, uncover gaps in the current body of literature, and develop innovative research questions that push the boundaries of knowledge in this field. Furthermore, these insights serve as a basis for developing targeted publication strategies, ensuring that research outputs align with the evolving interests and priorities of the academic community.

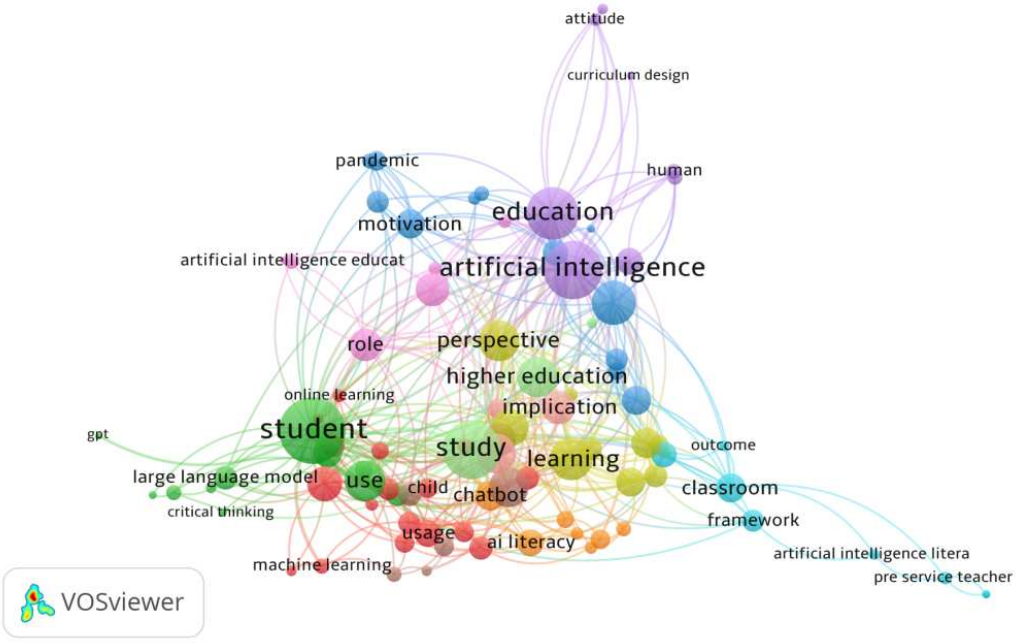

Figure 5. Co-Occurrence Network of Research Themes Based on Author Keywords

The data visualized in Figure 5 are derived from keywords designated by the article authors, and a co-occurrence analysis is used to identify patterns within the data. This method considers a maximum of 3 words per keyword across the 181 articles processed. Out of this total, 92 keywords met the predetermined threshold for inclusion in the analysis, ensuring that only the most relevant terms were considered. The dominant keywords identified in publications related to AI in Education include "artificial intelligence," "education," "student," "learning," and "study," reflecting the core themes that underpin current research in this area.

Figure 6 presents opportunities for future research. Emerging research opportunities center on keywords such as "GPT" (Generative Pre-trained Transformer), "artificial intelligence education," "artificial intelligence literacy," "curriculum design," and "learning outcomes with AI." These keywords indicate promising directions for future studies, underscoring the need to strategically optimize the implementation of artificial intelligence technologies in educational settings to enhance learning processes and improve educational outcomes.

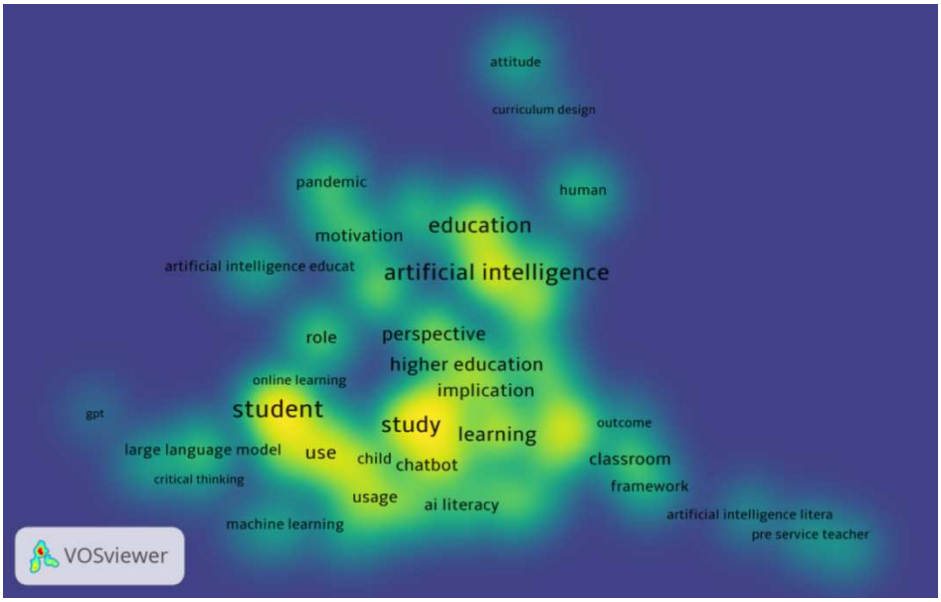

Figure 6. Co-occurrence Density of Research Themes Based on Author-Provided Keywords

AI in education is an ongoing research domain actively examined and advanced in contemporary academic literature (Ouyang & Jiao, 2021; Wang et al., 2024). Research is continuously conducted to examine how AI can assist in achieving educational goals (Rejeb et al., 2024; Seo et al., 2021). The study "Mapping Research on Artificial Intelligence in Education: A Bibliometric Analysis" introduces significant novelty in mapping

scholarly work on the application of artificial intelligence (AI) in education. The primary contribution of this research lies in its comprehensive bibliometric analysis approach, which integrates quantitative data from diverse scientific publications to identify emerging trends, collaborative networks, and key research themes within the field. Unlike previous narrative literature reviews, which are often descriptive and limited to selective samples of articles (Paul et al., 2021; Snyder, 2019), this study employs a data-driven methodology to provide a systematic and objective overview of global AI-in-education research developments.

The study's novelty is especially evident in its application of network visualization approaches, such as co-citation analysis, keyword co-occurrence, and collaboration mapping, which enable researchers to identify research clusters, influential scholars, and leading countries and institutions in the field (Bharti & Meera, 2021). The approach promotes a more detailed exploration and interpretation of the intellectual dynamics and evolving trajectories of AI-in-education research, which had not been systematically explored in prior studies. Future researchers are expected to explore in greater depth topics such as the impact of AI use in education, the role of AI in enhancing student engagement, the implementation of AI in automated assessment, and the ethical and privacy implications of AI use in education. Each of these topics offers opportunities to examine the influence and capabilities of artificial intelligence in enhancing learning experiences across various educational contexts (Lee & Kwon, 2024). The theme has not yet been exhaustively explored, offering a valuable opportunity for further research.

In addition, improving teacher competency through AI training is also a topic worth researching (Galindo-Dominguez et al., 2024). Furthermore, there is an urgent need for training to enhance teachers' competencies, especially in preparing experienced teachers. The exploration of teaching practices that incorporate AI-based learning media represents a significant area that warrants further investigation through rigorous research methodologies. Developing a teaching practice model that effectively integrates advanced technologies, such as Artificial Intelligence (AI), into the educational process is critically important. This study provides a robust theoretical and methodological foundation for subsequent research. By offering a comprehensive intellectual map, it assists researchers in identifying research gaps, avoiding duplication, and focusing efforts on underexplored areas, such as the ethics of AI use, student engagement, and the development of teacher competencies to confront advanced technologies.

CONCLUSION

Artificial Intelligence in Education has become a prominent theme in academic research, with significant growth in publications throughout the past half-decade, particularly after the declaration of COVID-19 as a global pandemic in 2020. This surge is primarily evident in European countries, driven by factors such as research funding, administrative policies, technological readiness, and the need for innovative solutions in distance learning and online instruction. Prominent researchers like Ismaila Tematiyo Sanusi, Thomas K.F. Chiu, and Davy Tsz Kit Ng have made substantial contributions, particularly in journals at the intersection of computer science and education, such as *Computer and Education: Artificial Intelligence*. The application of AI has immense potential to enhance educational quality by facilitating adaptive, effective, and inclusive learning. Bibliometric analysis underscores critical areas for future exploration, including the influence of Artificial Intelligence on learning outcomes, learner engagement, automated assessments, and the ethical considerations surrounding its use in education. Beyond merely mapping trends, research in this field has begun to yield tangible impacts on educational practices at various levels. Bibliometric analysis outcomes help stakeholders design more targeted strategies for educational technology development. Consequently, research findings mapped through bibliometric approaches not only provide conceptual and theoretical contributions but also carry significant implications for strengthening the global education system's performance, accessibility, and standards.

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