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ARTIFICIAL INTELLIGENCE IN EDUCATION: A KNOWLEDGE MAPPING APPROACH AND DISCUSSION OF HUMANISATION CHALLENGES

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The integration of artificial intelligence (AI) in education is transforming traditional teaching paradigms, opening up new possibilities for personalised, effective, and accessible learning; meanwhile, the discussion about ethical usage and bias is still growing. This study uses a knowledge mapping approach to explore the research landscape of AI in education by systematically analysing key research topics, trends, and knowledge gaps. It also discusses and explores the emerging debates on the use of AI as a "humanizer" and its impact on academic integrity. A bibliometric analysis was conducted on Scopus-indexed publications from 1976 to 2026. Network visualisation methods implemented in VOSviewer were used to examine publication growth, patterns of international collaboration, most influential studies, keyword co-occurrence patterns, and bibliographic relationships at the journal level. The results demonstrate the evolutionary nature of artificial intelligence applications all over the world from the perspectives of most cited works, collaborations among countries etc., the interdisciplinary collaborations that drive innovations, and the ethical issues associated with its implementation. This study provides a comprehensive overview of the current state of research highlighting the main trends, like countries with the most contribution in AI research in education are the USA and China, the biggest rise of AI research was seen from 2020 and 2024. However, despite the fact that AI is strongly influencing education processes, the study also discusses ethical aspects, like what should be done (and what can be at all), if a text is humanised?

Keywords: *Artificial intelligence, bibliometric analysis, education, humanisers.*

1. INTRODUCTION

An analysis and evaluation of artificial intelligence (AI) in education holds significant potential to tackle major challenges in education, revolutionise teaching and learning methods, and drive progress toward achieving Sustainable Development Goal 4 (SDG 4 – Ensure inclusive and equitable quality education). However, the swift pace of technological advancements has introduced numerous risks and challenges that have outstripped current policy discussions and regulatory measures [1].

As interest in AI and education continues to grow, the Education 4.0 Alliance aimed to explore the current landscape and future potential of this technology in the educational sector. Their most recent report by World Economic Forum [2] highlights four key promises that have surfaced regarding AI's role in facilitating Education 4.0. Supporting teachers' roles through augmentation and automation, refining assessment and analytics in education, supporting AI and digital literacy and personalising learning context and experience are mentioned as the main four key aspects of the analysis.

Research carried out in Ukraine regarding artificial intelligence and education in 2024 reveals that there is a very positive attitude towards artificial intelligence tools, in which all stakeholders recognise what artificial intelligence can offer to education. However, there were concerns regarding the accuracy of artificial intelligence tools and their suitability in education. The research further confirms that artificial intelligence in education is becoming increasingly accepted; however, concerns regarding artificial intelligence tools need to be addressed. To implement artificial intelligence tools in education successfully, strategies need to be considered to ensure student engagement and institutional goals. These strategies need to address various stakeholder expectations [3]. Here we understand – when GhatGPT was just launched, AI generated text was easily recognised, but now, when a lot of humaniser tools are freely available, education is transforming. Can we be sure that the text was truly not generated by AI, and should we concentrate on that so much instead of reforming the education system? According to the Organisation for Economic Co-operation and Development (OECD), AI may impact many aspects of the student future work, such as the economy, society, and the education system that prepares students for these changes. Therefore, it is essential to understand the capabilities of this technology and its development path. Additionally, comparing abilities of the AI to human skills is crucial in determining where AI can replace humans and where it can enhance their work. Are we ready to discuss it now? This understanding will help forecast which tasks AI might automate and how it could alter the demand for certain skills. Policymakers can leverage this knowledge to adjust education systems to future skill requirements and design targeted labour-market policies [4]. However, the Council of Europe [5] acknowledges the need to address issues related to such aspects as data privacy, algorithm transparency, and bias reduction in the use of AI in education. It is highlighted that it is important to ensure that the implementation of AI

systems upholds human rights principles and respects the dignity of all learners. According to the World Bank, the AI revolution is rapidly transforming education, providing innovative opportunities to tailor learning experiences, assist teachers and students in their daily activities, and enhance educational management [6].

Recent developments in Artificial Intelligence (AI) have sparked significant optimism about its potential impact on education and learning (AIED) [7]. AI-based modelling plays a critical role in designing automated, intelligent, and advanced systems capable of meeting contemporary needs [8]. The transformative potential of AI is widely acknowledged, with comparisons to foundational innovations such as oil and claims that it represents a pivotal moment in human history [7]. The global investments made in AI technology worldwide have led to the need to develop a framework to regulate the use of AI, with a particular emphasis on the education sector, where AI is believed to provide an enhanced learning experience while promoting AI literacy.

The concept of AI in the education sector has developed from computer science labs to a multibillion-dollar industry. Although there are some limitations to the use of AI, there is optimism that the technology will solve many of the problems associated with the traditional education system. As the AI technology improves, there is a need to investigate the ways through which the education system will leverage the technology to improve the academic performance of the students [9]. Over the last 25 years, AI has impacted the education system significantly, creating new opportunities as well as new challenges, mainly with regard to the learning experiences of the students [10].

The integration of Artificial Intelligence (AI) into education is rapidly reshaping the way teaching, learning, and administrative processes are conducted across the globe. As educational institutions strive to enhance learning outcomes and improve operational efficiency, AI technologies are increasingly seen as pivotal tools for achieving these goals. However, the vast and evolving landscape of AI applications in education necessitates a structured approach to understanding the scope, trends, and key areas of impact. This paper, *Artificial Intelligence in Education: A Knowledge Mapping Approach*, employs a knowledge mapping methodology to systematically analyse the current state of AI in education. By mapping the diverse applications, challenges, and research trends, this paper aims to provide a comprehensive overview of AI's role in education, highlight emerging patterns, and offer insights into future areas for research and practice in this transformative field.

2. RESULTS AND DISCUSSION

A systematic literature review and bibliometric analysis of academic articles on artificial intelligence in education published between 1976 and 2026 were conducted using the Scopus databases. The authors filtered scientific articles, selecting only articles where in the article title the following keywords were used: "artificial intelligence OR AI AND education".

2.1. Article Selection

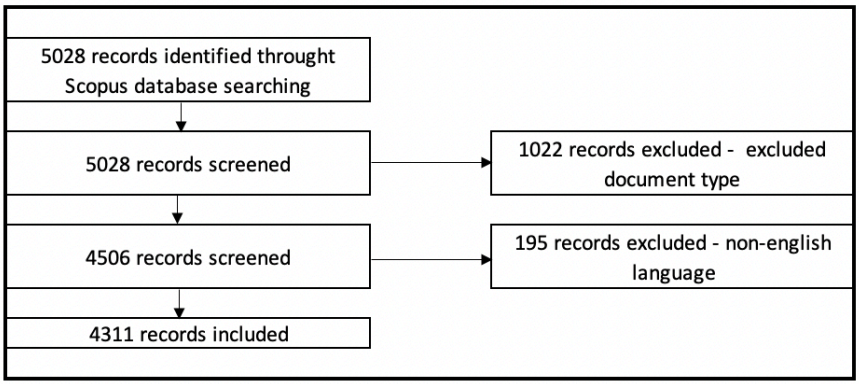

Fig. 1. PRISMA chart detailing the search results and number of articles included in bibliometric analysis, following PRISMA guidelines [11].

In following the PRISMA guidelines for 2020, transparency and rigor are ensured in the selection of relevant literature for the study and in the role that higher education plays in fulfilling the requirements for achieving SDG 13. A structured approach was utilised for the selection process.

Data were collected from the one of the most comprehensive and recognisable sources for social sciences research – Scopus database in January 2026. The relevant literature was selected based on specific criteria: only full-length research articles written in English were included, excluding materials like book chapters and conference papers. The keywords "Artificial Intelligence" or "AI" and "Education" were used to identify suitable studies and combine the sample. Following searches by title, 5,028 articles were retrieved from the Scopus database. After screening the results, the authors retained only articles, conference papers, book chapters, reviews, and books, yielding a total of 4,506 publications. After selecting only papers written in English, 4,311 publications remained.

2.2. Data Analysis

For the data analysis, VOSviewer 1.6.20. was employed as an instrument for creating a visual representation of the findings of the research. VOSviewer is an acknowledged powerful tool for carrying out bibliometric analysis. It can create visualisations of data using different criteria such as keyword co-occurrence, author collaborations, citations, and many other parameters. This tool is crucial for gaining an in-depth understanding of complex research environments. It achieves this by presenting complex data in visualised manner that all the associations between different parameters of research are clearly represented. This is done in the form of network diagrams. The use of VOSviewer for analysing the data is significant for gaining an enhanced level of interpretability of the findings of the research. It is capable of creating an understandable representation of complex research findings presented in the form of network diagrams.

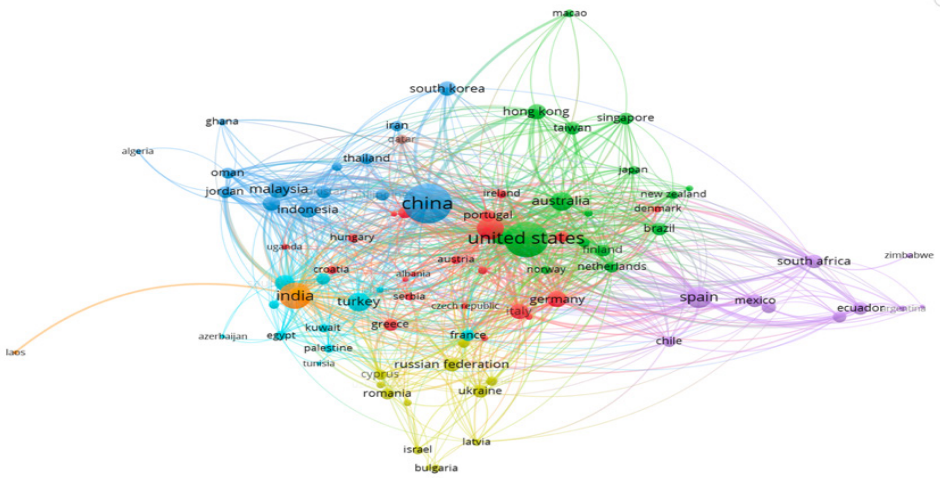

Fig. 2. Global collaboration network of countries.

The pioneering study in this field was published by Robertson [12] in Nature in 1976, and a further 4310 full-length articles on this subject were published between 1976 and 2026. The main contributor country of the topic is China with 988 documents from the Scopus database, followed by the USA with 671 articles and India with 372 articles. Figure 2, which was generated using VOSviewer (version: 1.6.20.), presents the visualisation of the global collaboration network of countries. The international collaboration network for the study of artificial intelligence in education consists of nodes representing countries and edges connecting them to signify co-authorship ties. Node size represents the volume of publications, and the density of the edges represents the collaborative ties between countries. The search terms for the dataset – artificial intelligence and education – do not affect the network structure but are the basis for the dataset creation.

From this network, a highly centralised collaboration structure dominated by a few "core" countries emerges. The most central country in this network is the United States. The United States plays a major hub role, linking many regional clusters. The strong ties that connect the United States to countries like China, the United Kingdom, Australia, and many other countries in Europe indicate that this country plays an important role in coordinating collaborative research worldwide rather than in national production. The centrality of this country not only indicates a high production volume but also a strong tendency toward co-authoring.

China and India are prominent secondary hubs with specific collaboration patterns. China has a high level of connectedness with the countries of East Asia and Southeast Asia. Specifically, South Korea, Malaysia, Indonesia, and Thailand are the countries with which China has a high level of collaboration. On the other hand, India has a high level of productivity; however, its collaboration pattern seems to be dispersed with countries in Asia, the Middle East, and Europe.

Countries in Europe are densely interconnected, and the UK, Germany, Spain, Italy, and France are significant intermediaries between the US centred core and

peripheral countries. The densely interconnected European countries are also a result of established research approaches and financial support that encourage cooperation among several countries. The significant links between Spain and countries in Latin America, such as Mexico, Chile, and Ecuador, also highlight linguistic and historic influences. Figure 3 presents the number of articles during the entire research period.

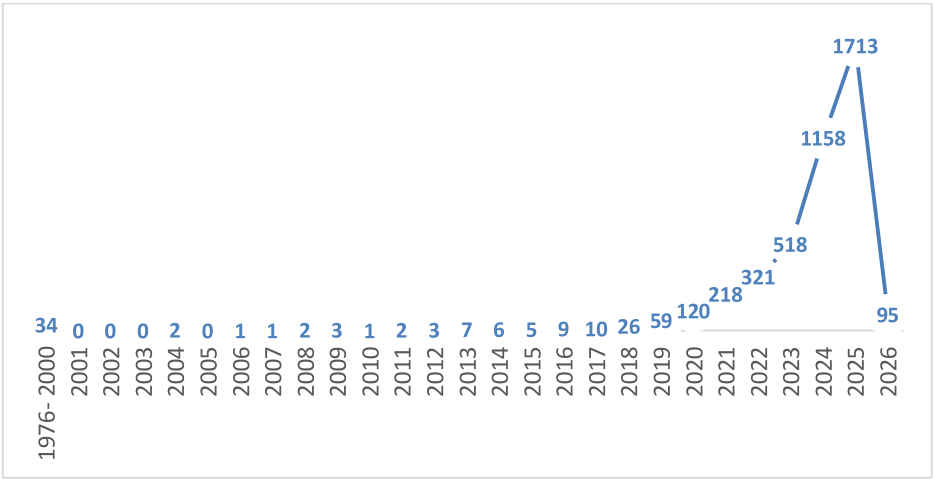

Fig. 3. Number of articles published in the Scopus database from 1976 to 2026.

The data provided in Fig. 3 show the number of articles published per year starting from 1976 to 2026, visualising a significant evolution in research on AI in education trends for all time periods in Scopus. In the period from 1976 to 2000 (for better visualisation, years were combined in Fig. 3 as the number of the publications is relatively small compared to other years), just 34 articles were published. This suggests that during this time, the AI in education was as topic in the early stages of development, averaging less than one article per year.

From 2001 to 2015, the growth in the number of articles was very slow. Most years in this period (2001, 2002, 2003, and 2005) saw no articles being published. The highest number of articles in any single year during this time was just two articles in 2004. However, since 2006, there has been a slight uptick in activity, with annual articles ranging from one to seven per year. The period from 2013 to 2015 showed a slight increase, with five articles published annually, but the growth was still relatively modest.

The most noticeable change occurred from 2016 to 2025, when the number of articles saw an exponential rise. In 2016, only nine articles were published, but by 2023, the number had reached 518, and in 2025, it peaked at 1,713 articles. This represents a consistent and rapid increase in the number of articles published annually, with the most significant growth happening after 2018. The increase from 2020 to 2021 was particularly sharp, going from 120 articles in 2020 to 218 in 2021, indicating a strong surge in activity.

The period from 2020 to 2024 stands out as the most dramatic phase, with the number of articles increasing by a factor

of eight over just four years. The yearly growth rate between 2020 and 2025 is approximately 70 %, reflecting an exponential rise. This suggests a combination of factors, such as greater access to digital platforms, increased funding, or a surge in the relevance of the topic, all contributing to the rapid expansion in the number of published articles.

Table 1. Top 10 Most Cited Articles

Author(s)	Year	Title	Source	Total citations
Zawacki-Richter, O., Marín, V.I., Bond, M., Gouverneur, F.	2019	Systematic Review of Research on Artificial Intelligence Applications in Higher Education – Where Are the Educators?	International Journal of Educational Technology in Higher Education	3,228
Chen, L., Chen, P., Lin, Z.	2020	Artificial Intelligence in Education: A Review	IEEE ACCESS	2319
Popenici, S.A.D., Kerr, S.	2017	Exploring the Impact of Artificial Intelligence on Teaching and Learning in Higher Education	Research and Practice in Technology Enhanced Learning	1,166
Crompton, H., Burke, D.	2023	Artificial Intelligence in Higher Education: The State of the Field	International Journal of Educational Technology in Higher Education	918
Cooper, G.	2023	Examining Science Education in ChatGPT: An Exploratory Study of Generative Artificial Intelligence	Journal of Science Education and Technology	894
Zhai, X., Chu, X., Chai, C.S., … Yuan, J., Li, Y.	2021	A Review of Artificial Intelligence (AI) in Education from 2010 to 2020	Complexity	845
Pavljik, J.V.	2023	Collaborating with ChatGPT: Considering the Implications of Generative Artificial Intelligence for Journalism and Media Education	Journalism and Mass Communication Educator	738
Nguyen, A., Ngo, H.N., Hong, Y., Dang, b., Nguyen, B.-P.T.	2023	Ethical Principles for Artificial Intelligence in Education	Education and Information Technologies	733
Roll, I., Wylie, R.	2016	Evolution and Revolution in Artificial Intelligence in Education	Education and Information Technologies	733
Chen, x., Xie, H., Zou, D., Hwang, G-J.	2020	Application and Theory Gaps during the Rise of Artificial Intelligence in Education	Computers and Education Artificial Intelligence	721

Table 1 indicates that the intellectual foundations of research on artificial intelligence in education are strongly shaped by a small group of highly influential authors and predominantly review-based scholarship. For instance, the most frequently cited paper written by Zawacki-Richter and colleagues [13] presented a systematic review on the use of AI in higher education settings. The paper has gained a remarkably

high number of citations. Furthermore, the review conducted by Chen et al. in 2020 has become a leading paper on the topic [14]. This can be attributed to a high demand for review papers that often accompanies periods of rapid growth in a specific research field.

Past impactful contributions, like Popenici & Kerr [15] and Roll & Wylie [16] emphasise the concepts and evolutionary nature of artificial intelligence within higher education settings. These are considered foundational pieces from the initial phase where researchers attempted to grasp the potential for AI to transform the learning and teaching landscape. The continued elevated citation rate for these articles suggests the foundational concepts remain relevant despite the advancements in AI technology.

Other, even more recent, highly cited articles show that there has been a shift in focus to consolidating knowledge in the field and tackling new issues. The research conducted by Crompton & Burke [17] and Cooper [18] shows that, in recent years, AI, particularly generative AI such as Chat GPT, has become a focus of scholarly work, especially in relation to higher education and science education. The articles have been highly cited, despite having been published in recent years, reflecting rapid uptake and significant scholarly interest.

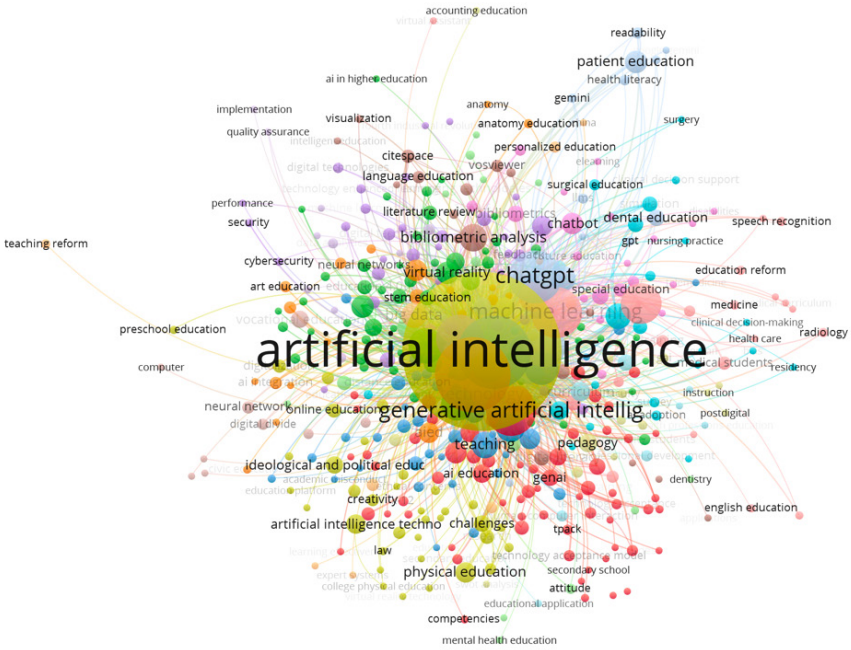

Fig. 4. Keywords of the selected articles.

Ethical issues and society are also represented in the top-cited literature. The article by Nguyen et al. [19] specifically addresses ethical issues in artificial intelligence in education. This is an encouraging sign of increased emphasis on sustainable approaches to AI use. At the same time, Pavlik [20] takes the debate beyond the boundaries of education and introduces issues of journalism.

A keyword co-occurrence network, which represents the concept structure of the body of knowledge on AI in education, is shown in Fig. 4. In this representation, the node sizes are based on keyword frequencies, and the proximity and connectiv-

ity of the nodes to other nodes are based on the co-occurrences of the keywords within the same publication. The dominance of the keyword "artificial intelligence" can be taken to imply its role as the central concept of the body of knowledge with several thematic clusters emerging.

The cluster related to machine learning, generative AI, and ChatGPT indicates a strong and relatively recent emphasis on data-oriented and generative methods. The co-location of ChatGPT with concepts such as teaching, pedagogy, special education, and language education suggests a relatively strong emphasis in the current literature on the educational applicability and implications of the technology rather than the technology per se. This mirrors the swift penetration of large language models in the educational discourse.

The second thematic cluster that can be identified pertains to the concepts of bibliometric study, literature review, VOSviewer, and CiteSpace. The appearance and prominence of these concepts suggest that the field is passing through a period of consolidation, characterised by systematic review and synthesis attempts to consolidate the rapidly expanding body of literature. The period aligns with the recent surge in the rate of publications and reflects the patterns identified in earlier bibliometric study on the field of educational technology.

The cluster of health-related education is specific, cohesive, and closely related to other keywords, such as "medical education", "dental education", "nursing practice", "radiology", "patient education", and "surgical education". This strong relationship with artificial intelligence emphasises the significance of professional education, which is considered a significant domain for the application of AI, focusing particularly on health education. This verifies the previous literature that indicated that the health sciences were among the first domains to adapt to AI-based education. Words such as *human* and *article* are frequently occurring terms, yet they possess limited conceptual specificity. This can be explained using such terms as an indexing or database-generated word, as opposed to an actual research concept. This phenomenon has been observed in prior bibliometric analyses, in which generic terms tend to appear as high-frequency nodes due to standardised indexing practices. Figure 5 presents the journal bibliographic coupling network.

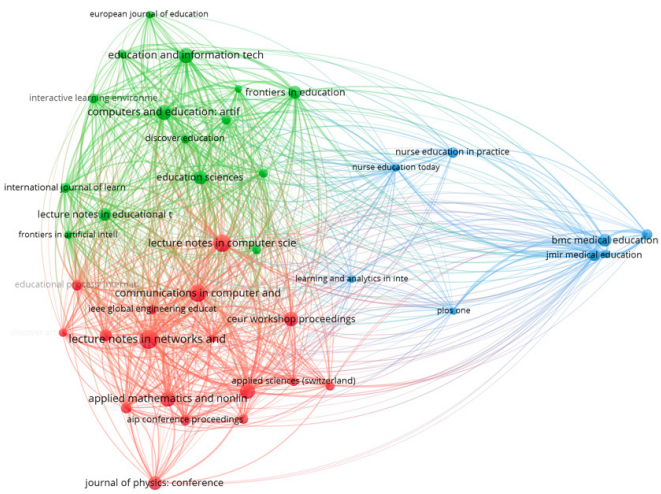

Fig. 5. Journal bibliometric coupling network.

The journal-level bibliographic coupling network reveals a clearly structured disciplinary landscape underlying research on artificial intelligence in education. Several large and centrally positioned journals function as intellectual hubs, indicating that AI-in-education research draws on – and contributes to – multiple established scientific domains rather than forming a single, self-contained field.

A prominent cluster is anchored by *PLOS ONE* and *Science*, which occupy central positions linking otherwise distinct disciplinary groups. Their bridging role reflects the interdisciplinary nature of AI-related educational research, particularly where methodological innovation, data-driven approaches, and broad empirical applicability intersect. The presence of these generalist journals suggests that research in this area often aims for cross-domain relevance rather than remaining confined to education-specific outlets.

The second major cluster is dominated by chemistry- and materials-oriented journals such as *ChemInform*, *Journal of Applied Polymer Science*, and *Physical Review*. Although these journals are not educational in focus, their strong connectivity indicates that methodological advances, particularly in modeling, simulation, and machine learning, are being transferred into educational research contexts. This cluster highlights the influence of computational and physical sciences on AI-related educational methodologies.

Another distinct cluster consists of journals rooted in life and health sciences, including *Journal of Biological Chemistry*, *European Journal of Neuroscience*, *BMC Public Health*, and *Journal of Advanced Nursing*. The cohesion of this group suggests that medical, health, and neuroscience education represent a major application area for artificial intelligence, where simulation, decision support, and training optimisation are especially prominent.

Computer science and engineering venues, such as *Lecture Notes in Computer Science* and *Communications of the ACM*, form an additional cluster characterised by high publication volume and dense internal connectivity. This reflects the role of conference-driven dissemination and rapid methodological development in shaping AI tools that are later adopted in educational contexts. Their position between technical and applied clusters underscores their function as conduits for transferring innovations into education.

3. CONCLUSION

This study employed a knowledge mapping and bibliometric analysis approach to examine the evolution, structure, and thematic orientation of research on artificial intelligence in education from 1976 to 2026. By systematically analysing publications indexed in the Scopus database and visualising patterns using VOSviewer, the study provides a comprehensive overview of how the field has developed over time, identifying dominant research themes, leading contributors, and emerging areas of interest.

The findings demonstrate that the research in artificial intelligence in education has transformed over time from a niche and exploratory research to a growing and very interdisciplinary research. Although the early research was limited in quantity and mainly conceptual in nature, the period after 2018 shows a stage characterised by exponential growth in response to develop-

ments in machine learning, data analytics, and recently generative AI technologies. The sharp rise in the number of publications between 2020 and 2024 shows both technological and international focus on digitalisation in education.

Moreover, the intellectual roots of the field appear to be significantly influenced by the body of research conducted through the lens of reviewing/synthesis-based research, particularly in the realm of higher education research. In parallel, the appearance of new clusters of research on the topics of generative AI, health/medical education, as well as bibliometric methodologies, indicates the diversification of research applications and the maturation of research viewpoints.

Analysis of the collaboration on an international scale indicates a highly interconnected yet uneven global environment in the context of scholarly activities conducted across the globe. A small group of nations, including the USA, China, and several European nations, has emerged as the core hubs of scholarly activity worldwide, while other nations are less represented in this context.

The study also underscores the increasing significance of ethical, governance, and policy issues related to artificial intelligence in education. The increasing prominence of the body of knowledge on issues of transparency, bias, data privacy, and use of artificial intelligence reflects the growing awareness of the imperative to advance technology within the context of humanistic and human rights-based education values. While this study has provided many useful findings, it has a few limitations. The study focused only on the Scopus database and on literature written in English. Further research can consider more databases and perform a longitudinal study to identify themes using this research model, in addition to qualitative analysis methods.

Apart from the identification of the existing research landscape, the results also suggest that the topic of AI in education is a highly relevant issue, with implications that transcend the technology itself. The speed with which AI is being incorporated into education suggests that these technologies are an integral, rather than a fleeting, aspect of learning environments, past, present, and possibly into the near future.

While there is an increased focus on the ethics of use, transparency, and academic integrity through various institutional and policy-based guides, there are still challenges that are yet to be resolved in the effective regulation and evaluation of AI-based learning. For one, the advent of technologies that aim to hide or "humanize" the content produced by AI poses a question regarding the effectiveness of various evaluation processes that are currently available, as well as the possibilities of separating human- from AI-supported work. Such a scenario presents a critical juncture for various institutions.

At the same time, the application of AI technologies in the education sphere cannot be explained solely as the delegation of students' tasks. This is because the proper application of AI technologies involves domain expertise, critical thinking, and the ability to articulate clear and relevant queries. From this perspective, the application of AI technologies can change the focus of the education sphere from the production of content to the development of students' cognitive capabilities, including evaluation, synthesis, or ethics. Future research on the application of AI technologies should not only focus on the capabilities of the technologies but also on the development of appropriate frameworks that determine the proper application of the technologies.

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