Perspectives on the Use of Artificial Intelligence in Education: a Bibliometric Review

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Abstract

Artificial intelligence has seen significant advances in recent years and represents an emerging technology that has revolutionized the way humans live. This technology is already being introduced in the field of education, although many teachers are unaware of its scope and, above all, of what it consists. Therefore, the present study shows the global production of scientific literature on artificial intelligence and education in the Scopus database between 1976 and August 2023. A sample of 1,280 documents was extracted from 612 sources. The results reveal a predominance of original research articles. As for the author with the greatest impact, Gwoyen Hwang stands out with an h- Index of 74 and more than 20 thousand citations in general. The most cited article is "Systematic review of research on artificial intelligence applications in higher education – where are the educators", and the magazine Lecture Notes in Computer Science is the most productive source. Among the countries of origin of studies on AI and education, China stands out with the highest number of publications, as well as the highest impact index on the subject.

Keywords

bibliometric indicators; artificial intelligence, university, education, generative AI.

1. First level sectioning

The innovations that artificial intelligence (AI) has been introducing in the various fields of human endeavor have generated controversies on such a scale that it has forced experts to rethink its impact and ethical implications of its use (Bozkurt et al., 2021; Wamba et al., 2021; Yu & Yu, 2023). In the field of education, AI helps improve the quality of the learning experience since its use allows the teacher to personalize learning, provide virtual tutoring, perform automated evaluations, detect cases of plagiarism, perform virtual simulations, among others.

The term was first used in 1955 by the American computer scientist and mathematician John McCarthy during the Dartmouth Conference, one of the most important events in the history of AI. The first signs of its application and development began to occur in the 80s and 90s with advances in natural language processing and its commercial applications. Between 2000 and

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2010, advances emerged in voice recognition processes, spam filtering, and the development of more sophisticated virtual assistants and recommendation systems. Starting in 2020, the use of AI burst into more complex sectors such as healthcare, automotive, supply chain management and cybersecurity (Sanabria-Navarro et al., 2023; Salmerón Moreira et al., 2023).

Among the most important innovations, the development of generative AI stands out, which allows generating diverse and contextually relevant content (Walczak & Cellary, 2023; Kshetri, 2023). Generative AI is a form of artificial intelligence that uses machine learning and deep analysis (Yu & Gou, 2023). It leverages the availability of large-scale data and advances in deep learning algorithms to develop models that learn from underlying patterns in the data to generate novel results with high-quality precision and clarity. This subfield of AI also helps generate images and music from input data. Currently there are several generative AI systems such as GPT-4, Open Assistant, DALL-E, Midjourney and others that have changed the landscape of information acquisition and learning.

In recent years, various studies have been carried out on the application of AI in the educational sector. Among them, studies on the contributions of AI in education policies stand out (Zhang et al., 2023); its inclusion in medical education (Ejaz et al., 2022); the responsibility of human beings in making decisions for their inclusion in education (Doroudi, 2022; Ninaus & Sailer, 2022); Generative AI and its contribution to education (Yu & Gou, 2023; Ahmad et al., 2023); the AI methods used to improve the education experience (Mallik & Gangopadhyay, 2023); the design of learning environments based on this technology (Leitner et al., 2022; Han et al., 2022), among many others. Now, despite its progress in terms of applications and proposals for use, controversies have not stopped arising, especially when the role that AI should play in education is brought up (Cukurova et al., 2019a), as well as if its use could replace the human being or be a human assistance technology (Cukurova et al., 2019b). However, the evidence so far has shown how useful its inclusion is for education, especially in times of pandemic where it played a leading role in the migration process from in-person to virtual.

Given that studies on AI and its application in the educational field have grown over the years, this bibliometric analysis sought to present the current panorama of this technology through an exhaustive review of the existing literature. The results can be of great help to education professionals when developing effective strategies that contribute to the use of AI and its implications at all educational levels. Also, it is important to highlight that this study provides valuable information about authors, sources, growth, trends and topics of interest about AI, which is significant for the understanding and advancement of research in this field.

2. Materials and methods

2.1. Search methods

Scopus database was used, the search period spanned from 1976 to August 2023. The keywords were checked by constantly filtering to corroborate the results. For the search, the following formulas were generated: (TITLE (artificial AND intelligence) OR TITLE (machine AND intelligence) OR TITLE (cognitive AND computing) OR TITLE (computer AND intelligence) OR TITLE (robotic AND intelligence) OR TITLE (automated AND intelligence) OR TITLE (artificial AND artificial intelligence) OR TITLE (machine AND learning) AND TITLE (education)). The data were exported to Microsoft Excel 2019. After organizing the information, it was confirmed that there were no duplicate articles.

2.2. Data extraction and analysis

The topic was chosen due to its novel nature, which is why the use of specific filters was not necessary. Once the database was obtained, each of the documents was reviewed in order to verify their relevance to the study. After this process, 1,280 documents were chosen that met the eligibility criteria, that is, addressing the educational field at any of its levels as the main topic.

Four documents were excluded because they were not part of the educational theme. The rest of the results were converted to CSV (comma separated values) and RIS (Research Information System) formats to perform the analysis (Vasconcelo-Alvarez et al., 2016). For the evaluation, the software Bibliometrix (Aria & Cuccurullo, 2017) and VOSviewer (Van Eck & Waltman, 2010) were used. Figure 1 shows the stages of the research.

Figure 1. Stages of the investigation.

3. Results

3.1. Initial data analysis

A total of 1280 articles from the Scopus database were analysed from 612 sources. The search period was from 1976 to August 2023. Table 1 shows general information about the documents. An annual growth rate of 12.84% was evident. There was also a high average of citations, close to 7 citations per published document.

Table 1
Information on the main bibliometric data

Description	Results
Main data	
Period	1976-2023
Sources (journals, magazines, books and others)	612
Documents	1280
Annual growth rate	12.84
Average age of the document	2.82
Average number of citations per document	7,466
References	35643

3.2. Information about authors

Regarding the authors (see Table 2), the analysis showed a total of 2930 authors of the 1280 documents collected. Of this number, 327 were single authors. The average number of authors per document was 3, while 16.17% of the documents had co-authorship or international collaborations.

Table 2
Bibliometric information about authors

Description	Results
Authors	
Authors	2930
Authors of single-author documents	327
Single-author documents	361
Co-authors per document	2.78
International co-authorships	16.17%

Regarding the initial data analysis, it was perceived that the type of document most frequently produced on artificial intelligence and education was the original article, followed by conference documents *(conference paper)* and book chapters (see Figure 2).

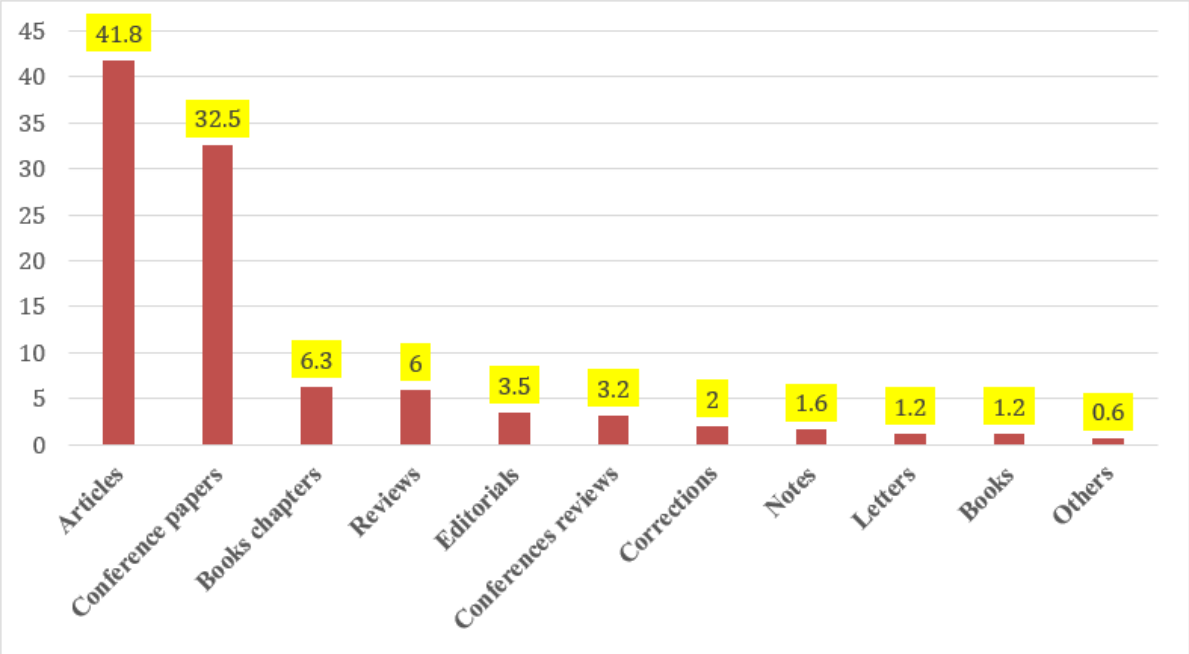

Figure 2. Bibliometric information on type of scientific document

3.3. Overall production

The global production per year is shown in Figure 3. A significant increase in research production can be observed from the year 1976 to the year 2022 (from 1 article to 376 articles). This data confirms the high annual growth rate, which is 16.17%. Figure 3 shows that in 2023, 292 documents have already been published, which confirms the validity and attractiveness of the topic for researchers. It is important to highlight that the production of scientific documents took off significantly starting in 2020, motivated by recent technological advances such as, for example, the emergence of practical and significant applications in the field of artificial intelligence or the development of models. of language like GPT-3 that allow machines to understand and generate text more effectively. These advances have sparked greater interest in the scientific community and industry, which has contributed to the development of the field of this technology.

Additionally, artificial intelligence is increasingly being used in a variety of practical applications, such as healthcare, autonomous driving, machine translation, and natural language processing. This has generated greater interest in the scientific community and industry, which in turn has driven the production of articles on the topic.

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3.4. Second level sectioning

3.4.1. Third level sectioning

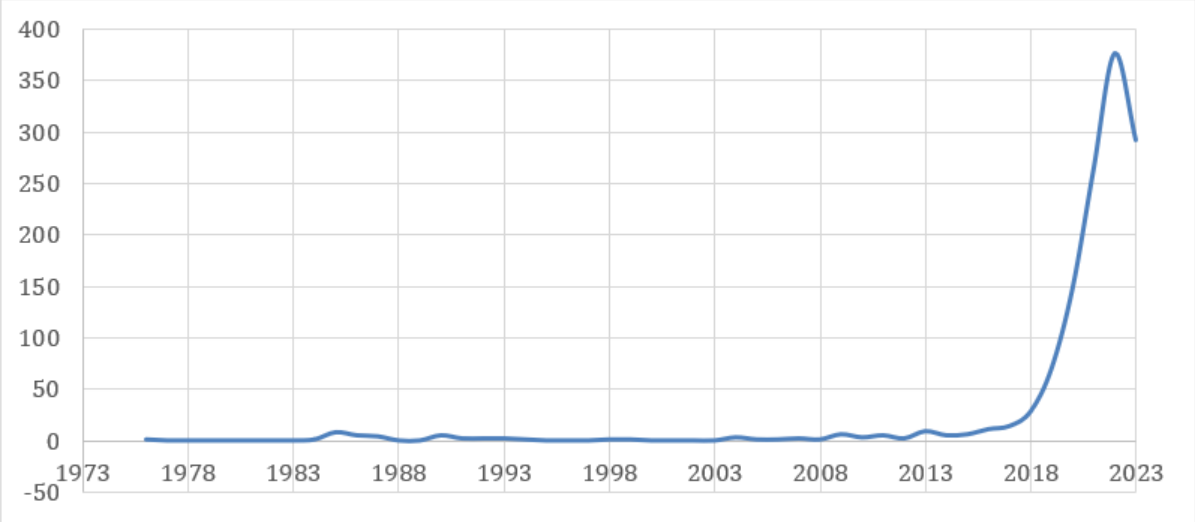

Figure 3. Annual research production

3.5. Sources

Regarding the most relevant sources, the magazine *Lecture Notes in Computer Science*, of *Springer* Nature publishing house stands out with 37 articles. In terms of impact, the magazine *Computers and Education: Artificial Intelligence* (of Elsevier publishing house) stands out with an h-index of 13 and 984 citations in total (see Table 3).

Table 3
Bibliometric information on the most relevant sources
Note: ACM (Association for Computing Machinery)

Sources	Articles	Scopus Quartile	Country	CiteScore 2022	Publisher
Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	37	Q3	Germany	2.2	Springer Nature
ACM International Conference Proceedings Series	29	Does not apply	USA	1.1	ACM
Journal of Physics Conference Series	29	Does not apply	United Kingdom	1.0	IOP Publishing Ltd.
Advances in Intelligent Systems and Computing	25	Does not apply	Germany	0.9 (2019)	Springer
Computers and Education Artificial Intelligence	25	Q1	Netherlands	7.7	Elsevier

International Journal of Artificial Intelligence in Education	25	Q1	USA	8.2	Springer

3.6. Most productive authors

Table 4 presents the authors with the greatest production of AI oriented to the field of education. Chinese researcher Gwoyen Hwang stands out as the most productive author on topics related to artificial intelligence, virtual reality and online learning. The Turkish researcher Utku also highlights Kose with related documents on application of AI in the medical field. In terms of impact, Gwoyen Hwang stands out with an h- Index of 74 and more than 20 thousand citations in general.

Table 4
Authors with the highest production in publications

Authors	h- Index	Most cited article regarding the topic AI-Education	Affiliation
Gwoyen Hwang	74	Vision, challenges, roles and research issues of Artificial Intelligence in Education	National Taiwan University Of Science and Technology
Utku Kose	twenty	Optimization of self-learning in Computer Engineering courses An intelligent software system supported by Artificial Neural Network and Vortex Optimization Algorithm	Süleyman Demirel Üniversitesi, Isparta, Turkey
Fan Ouyang	13	Artificial intelligence in education The three paradigms	College of Education, Zhejiang University, Hangzhou, China
Thomas K.F. Chiu	18	Sustainable resume planning for artificial intelligence education A self-determination theory perspective	Chinese University of Hong Kong, Hong Kong, China
Jiahong Su	6	Artificial intelligence in early childhood education: A scoping review	The University of Hong Kong, Hong Kong, China

3.7. The most cited articles

Table 5 lists the most cited articles in Scopus. The 2019 study "Systematic review of research on artificial intelligence applications in higher education – where are the educators?" by Olaf Zawacki-Richter, Victoria I. Marín, Melissa Bond & Franziska Gouverneur stands out. This article seeks to provide an overview of research on AI applications in higher education through a systematic review. The document has been cited 503 times, with an average of 100 citations per year since its publication in October 2019 in the *International Journal magazine of Educational Research and Practice in Technology Enhanced Learning* (Springer Open).

Also noteworthy is the article "Exploring the impact of artificial intelligence on teaching and learning in higher education" by Stefan AD Popenici and Sharon Kerr (2017). The study highlights the educational implications of emerging technologies on the way students learn and how institutions teach and evolve. Recent technological advances and the increasing speed of adoption of new technologies in higher education are explored. This article was published in 2017 in the journal *Research and Practice in Technology Enhanced Learning* (SpringerOpen).

The articles with the highest number of citations explore the use of artificial intelligence in education, from a qualitative point of view. Roll & Wylie (2016), for example, summarize this aspect very well by predicting two parallel lines of research that must be carried out to have an impact on education in the next 25 years: one is an evolutionary process, which focuses on the current classroom practices, collaboration with teachers, and diversification of technologies and domains; and the second, new technologies as a revolutionary process in which they must be integrated into the daily lives of students.

Table 5
Most cited peer-reviewed documents in Scopus
Note: TC = Total citations.

Author, Year	Journal	Qualification	T.C.	TC per year
Olaf Zawacki-Richter, Victoria I. Marín, Melissa Bond & Franziska Gouverneur, 2019	International Journal of Educational Research and Practice in Technology Enhanced Learning, 16(39), pp.1-27	Systematic review of research on artificial intelligence applications in higher education – where are the educators?	503	100.6
Stefan AD Popenici & Sharon Kerr, 2017	Research and Practice in Technology Enhanced Learning, 12(22), pp. 1–13	Exploring the impact of artificial intelligence on teaching and learning in higher education	307	43.86
Lijia Chen; Pingping Chen; Zhijian Lin. 2020	IEEE Access, 8, pp. 75264-75278	Artificial Intelligence in Education A Review	249	62.25
Gone Roll & Ruth Wylie, 2016	International Journal of Artificial Intelligence in Education, 26:582–599	Evolution and Revolution in Artificial Intelligence in Education	243	30.38
Joseph E. Aoun. 2017	Robot-Proof Higher Education in the Age of Artificial Intelligence. ISBN: 9780262535977	Education application of artificial intelligence technology Learning outcome and meta-diploma	208	29.71

3.8. Impact by country

The list of countries with the greatest impact on research on AI and education is led by China, with 2,026 citations in Scopus, followed by the United States with 771 citations and Australia with 712 citations (see Table 6). The country with the highest number of scientific documents is also China with 991 documents, followed by the United States (509), India (228) and the United Kingdom (139). On the other hand, China presents an SCP (intracountry collaboration) of 350 and an MCP of 27 (collaboration between countries), while the United States presents an SCP of 79 and an MCP of 9.

Table 6
Impact by country of origin of publications in Scopus

Country	Total citations	Average citation per article
China	2,026	5.4
USA	771	8.8
Australia	712	25.4
Hong Kong	610	24.4
Germany	606	37.9
Canada	570	24.8
United Kingdom	408	14.1
India	366	8.5
South Korea	291	10.4
Netherlands	141	70.5

The countries that have the highest number of collaborations are China and the United States (10 collaborations), China and Hong Kong (10 collaborations), and the United States and Canada (10 collaborations) (see Figure 4). It is important to highlight that collaboration between China and the United States in artificial intelligence research is essential given the importance and influence of their cultures. This collaboration will allow it to leverage its experience and resources, address global challenges, maintain its global competitiveness and ensure that artificial intelligence is developed and used ethically and safely for the benefit of humanity.

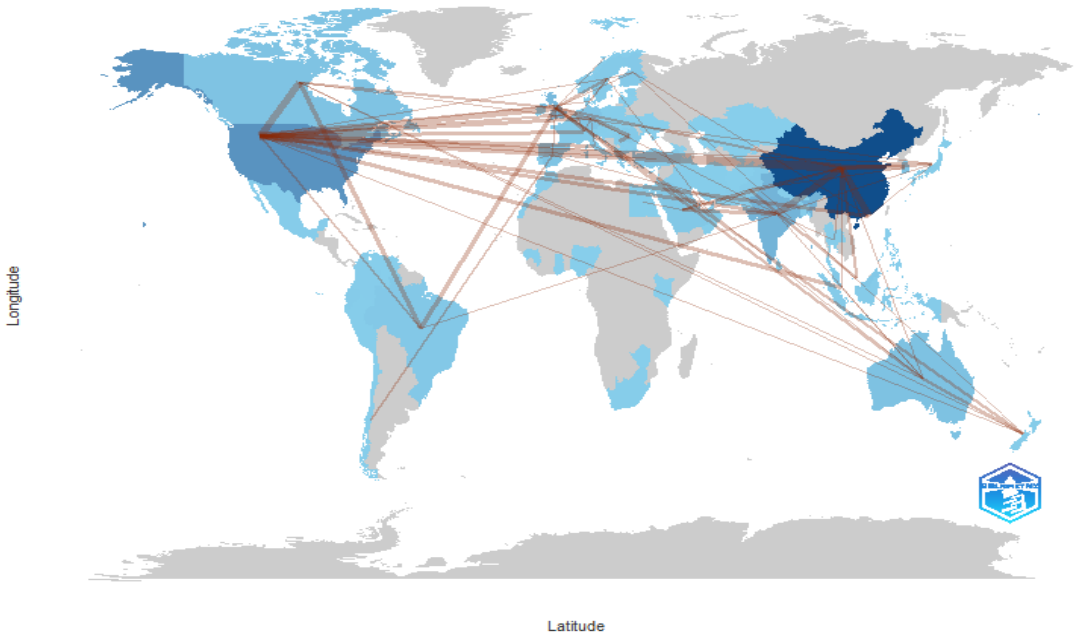

Figure 4. Global collaboration map

3.9. Co-occurrence analysis

Keyword co-occurrence analysis generated 7 clusters, 395 elements, 11807 links and a total edge strength of 28936. Cluster 1 (red), about *students,* had 148 occurrences and referred to the iterations of the artificial intelligence with the students. Group 2 (green), which highlights artificial intelligence as the main term, had 110 occurrences and refers to the general context of artificial intelligence in education. Cluster 3 (blue), on *education,* had 87 occurrences and referred to the various ways in which AI is applied in education. Group 4 (yellow), on *Deep learning,* had 25 occurrences and referred to various artificial intelligence techniques. Cluster 5 (purple), on

Covid 19, had 13 occurrences and referred to the impact of the pandemic on education. Group 6 (light blue) mentioned *health* and evaluated aspects related to health; and group 7 (orange), with the keyword *chat Gpt* had 6 occurrences mentioning this emerging artificial intelligence application (see Figure 5).

On the other hand, the most significant author keywords were *artificial intelligence* (with 789 occurrences), *students* (with 245), *engineering education* (with 153), *human* (with 146) and *teaching* (with 130), as seen in Figure 6. These keywords are the basis of the themes of the studies that have been generated in the current context. The axes of interest are directly focused on education in artificial intelligence, possibly with a focus on teaching artificial intelligence to engineering students, focused on technological and human aspects of this discipline.

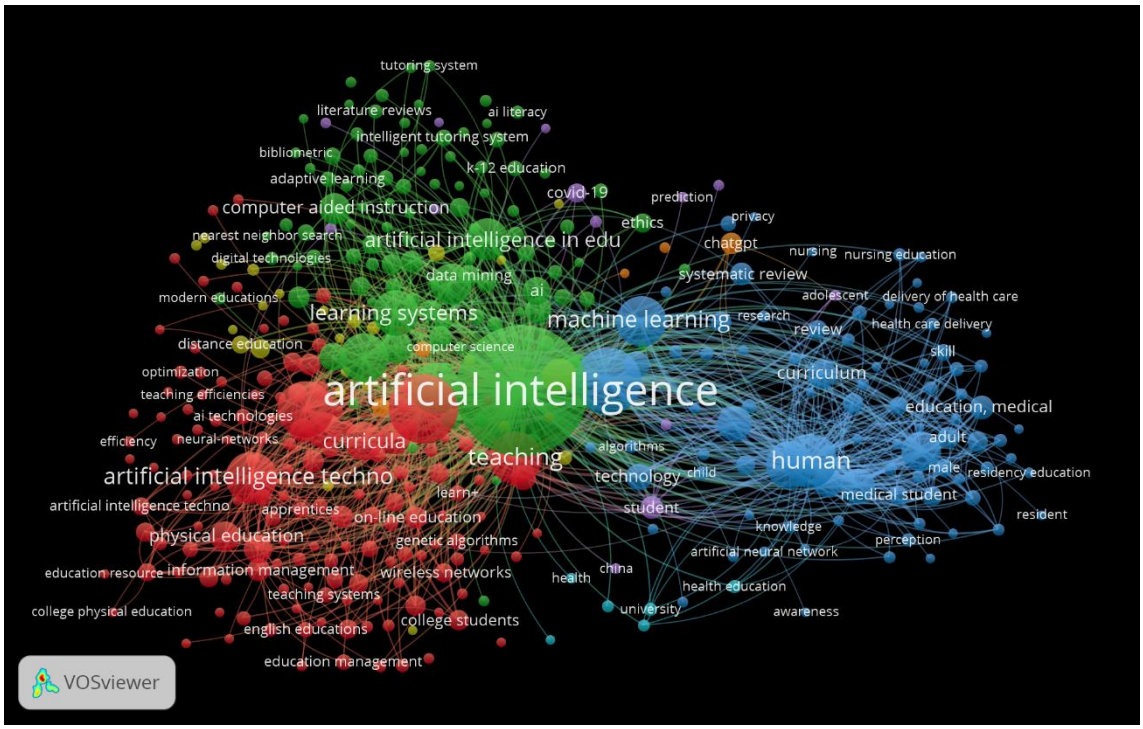

Figure 5. Analysis of co-occurrences in Scopus

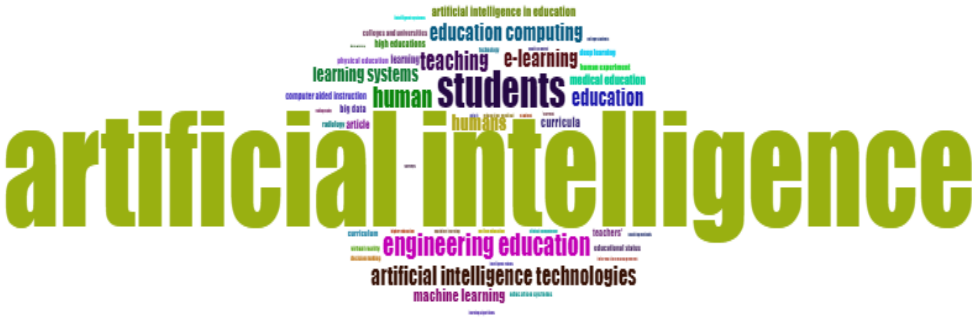

Figure 6. Scopus word map

3.10. Thematic map

Figure 7 illustrates the thematic map with the driving themes of high importance and development which are located in the upper left quadrant. The determination of driving themes helps drive the development of lines of research on artificial intelligence in general and topics

related to artificial intelligence technology, mental health education, and AI-based educational platform in particular. The map also highlights topics related to virtual reality technology in relation to the development of physical education.

Among the topics highly developed internally, but of low relevance, the applications of artificial intelligence, education and education systems based on it stand out. On the contrary, among the emerging or declining topics, represented by topics of low development and little importance in the academic world, generative artificial intelligence stands out. This term refers to artificial intelligence systems capable of generating content, such as texts, images or music, autonomously and creatively. Finally, in the upper left quadrant—as niche topics that constitute widely specialized research areas, of great importance but low development—research on artificial intelligence techniques and technologies stands out, in addition to their integration in education.

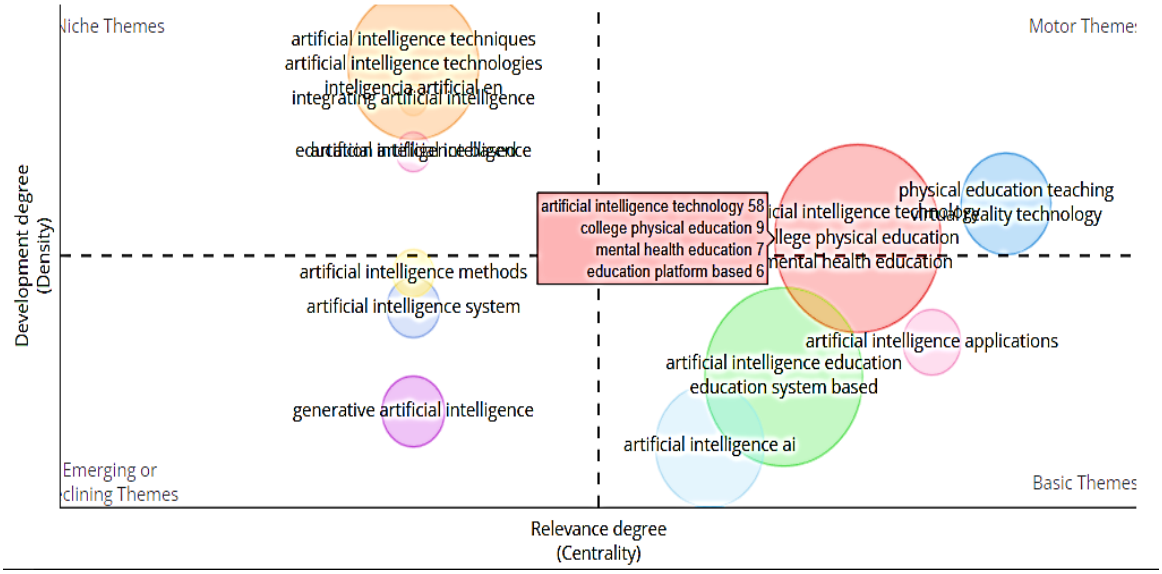

Figure 7. Thematic map taken from Scopus.

3.11. Factor analysis

The results of the multiple correspondence analysis (MCA), based on the Conceptual Structure Map (CSM) method, show the conceptual structure of the keywords associated with education and artificial intelligence used in the articles included in this study (see Figure 8). Keywords closest to the center point have been targeted with high frequency in recent years.

Now, the explained variance of dimension 1 (x-axis) reaches 23.81%, which is the highest value. On the contrary, the explained variance of dimension 2 (y-axis) is the least relevant with 21.38%. The red group of 14 words in the titles covers topics related to artificial intelligence, *machine learning* and *intelligence ai,* which are closer to dimension 1. While keywords such as education based on artificial intelligence are found in dimension 2. Group 2 (blue) is the least significant and is distant from the central point. This group is made up only of two keywords focused on aspects related to AI-based education.

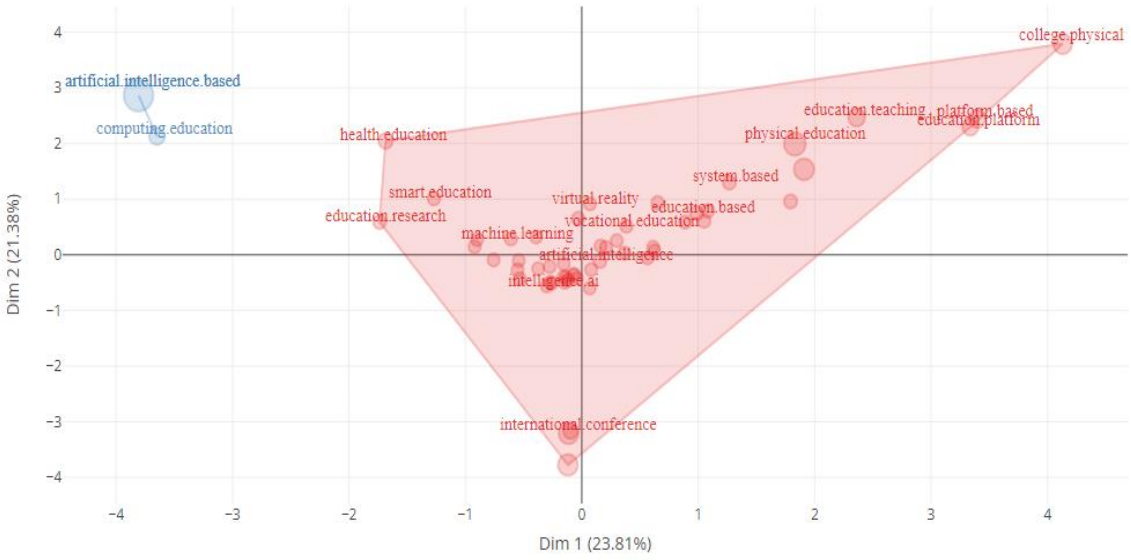

Figure 8. Factor analysis.

4. Conclusions

Bibliometrics is a type of quantitative analysis that uses various publication patterns (McBurney & Novak, 2002). The objective of this study was to conduct a bibliometric review of research on artificial intelligence in the context of education in the Scopus database. To do this, the characteristics of the publications, authors, sources, collaborations between authors and countries and research networks were analyzed. Artificial intelligence (AI)—an umbrella term that implies mimicking, with minimal intervention, the information process of intelligent behavior and senses—is one of the most promising areas of research and has received considerable attention, with coexisting pros and cons (Gao & Ding, 2022).

The study analyzed a sample of 1280 documents retrieved from the Scopus database, which were published in 612 scientific journals, with 35,643 references and an average citation count per document of 7.47. These documents were predominantly original articles (535), followed by *conference papers* and book chapters, results that coincide with the bibliometric study by Hinojo-Lucena et al. (2019), for whom these types of documents are the most common given the technological nature of the topic. Research output peaked in 2022, increasing at an annual rate of 12.84%. A significant growth in production is observed from 2017, motivated by the significant advances from that year on in terms of artificial intelligence, particularly in deep learning *(deep learning)* and natural language processing (NLP). These advances have allowed the development of more sophisticated tutoring and personalization systems for education. Add to this the Covid pandemic which accelerated the adoption of online education and, as a result, the importance of artificial intelligence in education became even more evident in improving the online learning experience. Ullrich et al. (2022), in their bibliometric study on artificial intelligence and teaching, corroborate this growth.

Regarding the most relevant sources, the magazine *Lecture Notes in Computer Science* stands out with 37 articles. In terms of impact, the magazine *Computers & Education Artificial Intelligence* stands out with an h index of 13 and 984 citations in total. For Hwang & Tu (2021) the journals with the highest number of articles published on artificial intelligence are *Computers & Education* (8) and *Journal of Educational Psychology* (5), which corroborates the results of this study. For their part, Rashid et al. (2021) highlight in their study the magazines *Computers & Education, International Journal of Emerging Technologies in Learning* and *Journal of Surgical Education* as the most productive in this field.

Researcher Gwoyen Hwang has the greatest production and impact in this field. The most cited article in Scopus is "Systematic review of research on artificial intelligence applications in higher

education – where are the educators?" by Olaf Zawacki-Richter, Victoria I. Marín, Melissa Bond & Franziska Gouverneur (2019), cited 503 times, with an average of 100 citations per year since its publication in October 2019, in the *International Journal of Educational Research and Practice in Technology Enhanced Learning* (SpringerOpen).

The country with the greatest impact on this topic is China with 2,026 citations in Scopus, while the country with the highest number of scientific documents is also China with 991. On the other hand, China presents an SCP (collaboration within the country) of 350 and an MCP of 27 (collaboration between countries). This result is consistent with the findings of Jia et al. (2022), Chen et al. (2021) and Ullrich et al. (2022), who corroborate that China is the most productive country in artificial intelligence. The countries that have the highest number of collaborations are China and the United States (10 collaborations), China and Hong Kong, and the United States and Canada (10 collaborations each). Along these lines, the study by Baek & Doleck (2020) shows a strong collaboration network between the United States and Canada.

Keyword co-occurrence analysis of the Scopus database generated 7 clusters, 395 items, 11807 links, and a total edge strength of 28936. Cluster 1 (red), includes key terms such as *students, artificial intelligence, education* and *Deep learning.* The terms *Covid 19 health* and *ChatGPT* also stand out as emerging topics. Bahroun et al. (2023) highlight ChatGPT as an emerging and dominant Generative Artificial Intelligence (GAI) tool. Pradana et al. (2023), for their part, highlight in its analysis of co-occurrence (co-occurrence keywords) "ChatGPT", "education" and "artificial intelligence" as the terms that appear most frequently. Pua et al. (2021) highlight "education", "learning", "system", "student", "teaching", "engineering education", "computer-aided instruction", "machine learning", "education computing" and "e-learning" as important words. Whereas Tenório Tenório et al. (2023) highlight "machine learning", "data", "big data", "deep learning" and "ethics'.

The thematic map highlights topics related to artificial intelligence technology, health education, and AI-based educational platforms. It also highlights virtual reality technology in relation to the development of physical education. Among the crucial core topics, internally highly developed but of low importance, artificial intelligence applications, education and education systems based on it stand out. Song & Wang (2020) point out that the development of research on educational artificial intelligence (EAI) was conceptualized as follows: (a) technological base; (b) technological advancement; (c) smart application; and (d) symbiotic integration, which are possible directions for future research on IAD.

In summary, regarding the research topic, studies in the field of AI related to education are growing. The current interest of researchers has focused on three directions: technology derived from artificial intelligence, health education using AI, and the development of educational platforms based on AI. It also highlights emerging research on chatbots such as ChatGPT. It should be noted that, as the topic of AI is growing, greater interdisciplinary research is required. Further research could emphasize student reactions, measure the effectiveness of studies, the combination of artificial intelligence technology with online learning, and the integration of applications between technologies in learning ecosystems (Oliva Córdova et al., 2019). Furthermore, future research could focus on taking teaching practices "one step forward" by integrating ChatGPT, in order to examine how humans and computers could collaborate to achieve an educational goal and examining the changes and results brought to the field of education (Paucar Curasma et al., 2022).

Despite the results obtained, this research has some limitations. First, the use of a limited number of keywords means that the results may be biased, since these could include some articles that do not analyze the topic studied in this article. The second is related to the database since it could contain undetected errors. For future studies on this topic, it is suggested to be more exhaustive when searching for articles. Not just the match with the keywords, but the match should be extended across the topics. In addition, the use of other databases such as Web of Science would be desirable.

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6. Data availability statement

The information included in this article is the result of the analysis carried out by the researchers. Readers or reviewers who require additional information to validate the content of the study should send their queries to the authors.

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