A Bibliometric Analysis of the Development of Artificial Intelligence (AI) Research in Education in Scopus Indexed Journals: What are the Future Trends of this Research?

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Abstract **– This study aims to provide an overview of the literature on artificial intelligence in education based on bibliometric evaluation of various journal articles published in the Scopus database, and identify knowledge gaps as a source for future research. The approach uses VOSviewer, SEforRA, and Publish or Perish for bibliometric analysis. The analysis's findings show that artificial intelligence in education research tends to expand on the Scopus database, with a peak observed in 2021 and a trend from 2018 to 2023. Numerous themes or keywords that potentially form the basis for additional research have emerged from the expanding corpus of research on artificial intelligence in education. Finally, the bibliometric analysis provides information on AI developments in educational research, which opens the door for further exploration, collaboration, and innovation in this rapidly growing field and offers valuable insights to understand future trends, challenges, and opportunities.**

Keywords **– Artificial intelligence, education, Scopus, bibliometric, research trends**

DOI: 10.18421/TEM141-60
https://doi.org/10.18421/TEM141-60

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Received: 18 June 2024.
Revised: 09 December 2024.
Accepted: 06 January 2025.
Published: 27 February 2025.

1. Introduction

The idea that artificial intelligence (AI) has strategic educational value is becoming increasingly popular [1], [2], [3], [4]. Artificial intelligence (AI) has the potential to be a helpful teaching tool that reduces workloads for both educators and students while giving the latter a more interesting learning environment [5], [6]. The development of AI applications in education has many opportunities, particularly when paired with modern educational innovations like gamification, digitalization of learning materials, and personalized learning experiences [7], [8], [9].

When the term artificial intelligence is used, a supercomputer comes to mind [10], [11]. With the addition of sensors and other features, these robots can display adaptive behavior and have enormous processing power, giving them human-like cognitive and functional capacities. These characteristics improve supercomputers' communication with humans [12], [13], [14]. Several motion pictures have been made to showcase the capabilities of artificial intelligence. The control of temperature, music, and air quality in smart buildings according to the mood of the occupants is one example of this. AI has become more prevalent in education, going beyond the conventional understanding of AI as a supercomputer to include embedded computer systems [15], [16].

These days, information technology plays a major role in daily life. Technology is developed to suit human requirements and facilitate work [17], [18]. Artificial intelligence is used in numerous industries, including education, to further the growth of information technology [19], [20]. Artificial intelligence is being used in education through chatbots, game-based learning, data analysis, adaptive learning, virtual tutors, and automatic evaluation. Three areas—learning, applied research, and training in AI application—are conditionally separated when it comes to the employment of digital and AI technologies in the educational process.

According to Paśko and Dong, artificial intelligence is a cutting-edge technology that facilitates communication between humans and machines [21], [22]. The capacity of computers to carry out higher-order cognitive tasks like observation, judgment, problem-solving, generalization, and experience acquisition is known as artificial intelligence [23], [24]. To address problems with education, artificial intelligence in education is an interdisciplinary field of research that combines methods and materials from several disciplines, such as computer science and information science. One use of artificial intelligence in education is the development of a problem-solving system that is capable of solving other problem-solving systems.

Research related to the use of artificial intelligence in education until now has been widely carried out and is still being studied, so a literature study is needed to find out the trend of artificial intelligence research in education to make it easier for future researchers to determine research themes. Some studies with bibliometric analysis research topics include - A bibliometric examination of the last 20 years' global advancements in educational artificial intelligence research [25]; A review and bibliometric analysis of artificial intelligence in education research during the past ten years [26]; Bibliometric analysis for the identification and examination of major themes in educational artificial intelligence research [27]; Higher Education and Artificial Intelligence: A Bibliometric Analysis of Its Effects on the Scientific Literature [28]; and Artificial Intelligence's Place and Research Trends in Mathematics Education: A Systematic Review and Bibliometric Mapping Analysis [29].

However, none of the aforementioned bibliometric analyses of AI in education resulted in the analysis of articles in Scopus-indexed journals. Therefore, the purpose of this study is to determine the extent of the development of artificial intelligence (AI) research in education studies between 1991-2023 in Scopus-indexed journals. From the above description, the research question (RQ) can be written as follows:

- RQ1. How do the findings of artificial intelligence (AI) research relate to and benefit the subject of education?
- RQ2. In Scopus-indexed publications, what are the most often used terms related to AI research issues in education, and how they changed or developed in the past several years?
- RQ3. Specifically, among journals with a Scopus index, which academics publish the greatest number of peer-reviewed articles on AI research in education?
- RQ4. Which esteemed journals, particularly those with a Scopus index, support AI research in education?

2. Research Methodology

The research technique makes use of the Publish or Perish application version 8 for article searches and the bibliometric analytic tools included in Vosviewer. Bibliometric analysis is one approach that is often used to assess trends and performance in a field. This method provides an objective and reliable way to assess the extent to which an article contributes to understanding of a particular field [30]. By highlighting research gaps and innovative ideas as the starting points for more studies, bibliometric analysis helps to clarify the growth of educational philosophy in the academic community. In the topic of artificial intelligence for education in Scopus-indexed papers, bibliometric analysis has not gotten as much attention as in many other disciplines, despite its vast exploration. It would be fascinating to pursue bibliometric analysis research in the area of artificial intelligence for teaching in journals that are indexed by Scopus.

Numerous studies have reported that bibliometric analysis can be used to find research trends and novelty [31], [32], [33], [34], [35], where the article documents are located in the Scopus database. This is predicated on Scopus's reputation as a trustworthy worldwide publication platform for scholars. The term "artificial intelligence in education" was used as a filter to search for titles, abstracts, and keywords from 1991 to 2023. The following were the general research techniques: (a) identifying the topic "mobile learning" using the Publish or Perish version 8 application; (b) optimizing Scopus Elsevier; (c) downloading RIS and CSV; (d) analyzing RIS data using VOSViewer software [30], [36]: (e) analyzing CSV data using Microsoft Excel; and (f) interpretation (g) Learn about trends in mobile learning research through profiles and headlines.

3. Results

Research on artificial intelligence (AI) in education has shown significant growth over the past few decades. In an effort to understand the trends and influence of this research, Elsevier's Scopus database was used as the primary data source. Through an automated search using the Publish or Perish (PoP) tool with the keyword “artificial intelligence in education” and a publication year range of 1991 to 2023, 200 relevant articles were obtained.

The analysis showed that the oldest article titled Artificial Intelligence in Education: Evolution of the Teaching-Learning Connection by M. Garito was published in 1991 with 9 citations. Overall, the 200 articles analyzed - received a total of 8,718 citations, with an average of 264.18 citations per year and 43.59 citations per article.

The analysis also revealed that the Hirsch index (h-index) of this study reached 47, indicating at least 47 articles was cited 47 times or more. In addition, the g-index of 84 highlights the significant cumulative influence of these works.

In terms of publications, the trend of AI research in education has shown an increase since 1991, with a peak in 2021 when 49 articles were published. This sharp increase is driven by wider *access* to the internet and supporting infrastructure, as well as the global open-access movement that makes it easier to publish scientific articles.

3.1. The Development of AI in Publications Related to Education

Elsevier's Scopus database provided the research data on the development of artificial intelligence in educational literature. Using the following data and the database from the Publish or Perish (PoP) tool: "Artificial intelligence in education" and "data search year" were the keywords that were chosen. An automatic data search year range of publishing years from 1991 to 2023 was provided. It was possible to obtain 200 papers in total. Based on this data, the oldest article was Artificial Intelligence in Education: Evolution of the Teaching-Learning Connection, by M. Garito, published in the British Journal of Educational Technology in 1991 and with a total of 9 citations.

Table 1. Metadata for articles

Citation Metrics	
Publication years	1991-2023
Citation years	33 (1991-2024)
Papers	200
Citations	8718
Cites/year	264.18
Cites/paper	43.59
Authors/paper	1.00
h-index	47
g-index	84

Table 1 presents data about the effectiveness or influence of artificial intelligence (AI) research within the educational setting. The publishing years, which span from 1991 to 2023, show when studies on artificial intelligence in education were released. The years that these works' citations were accumulated is, spanning from 1991 to 2023. This provides a more thorough understanding of the study's effect size over a longer time frame. There were 200 papers in all that were examined about AI in education. These papers have received 8718 citations in total.

The annual average for the number of citations received is 264.18. An article garnered 43.59 citations on average from other publications. One author on average contributed to each piece, suggesting that there may have been one author working alone or in conjunction with other authors. Research influence and popularity are gauged by the Hirsch index, sometimes known as the h-index. The h-index in this instance is 47, indicating that at least 47 citations have been made to each of the 47 articles. Although the most cited publications are more likely to be prioritized, the g-index is still a measure of research impact. The g-index in this instance is 84.

From 1991 to 2023, the average number of publications on artificial intelligence in education increased, reaching a peak of 49 articles in 2021 (Figure 1). The highest average number of articles published was in 2019 (20 articles), followed by 2020 (34 articles), 2021 (49 articles), 2022 (44 articles), and 2023 (33 articles). There was only one article published in each of the following years: 1991, 1993, 1998, 2004, 2009, 2012, 2014, and 2015. Based on Figure 3, the number of educational articles related to artificial intelligence increased significantly between 1991 and 2023, with a peak in 2021. This increase started after 2000 when the Internet became more popular and more accessible. [37]. The monthly data usage and worldwide internet traffic are consistent with the notable rise in the number of published articles. Infrastructure and media improvements have contributed to the rise in publications, which has been further fueled by the global open-access movement [38], which has resulted in a significant increase in the publication of scientific articles.

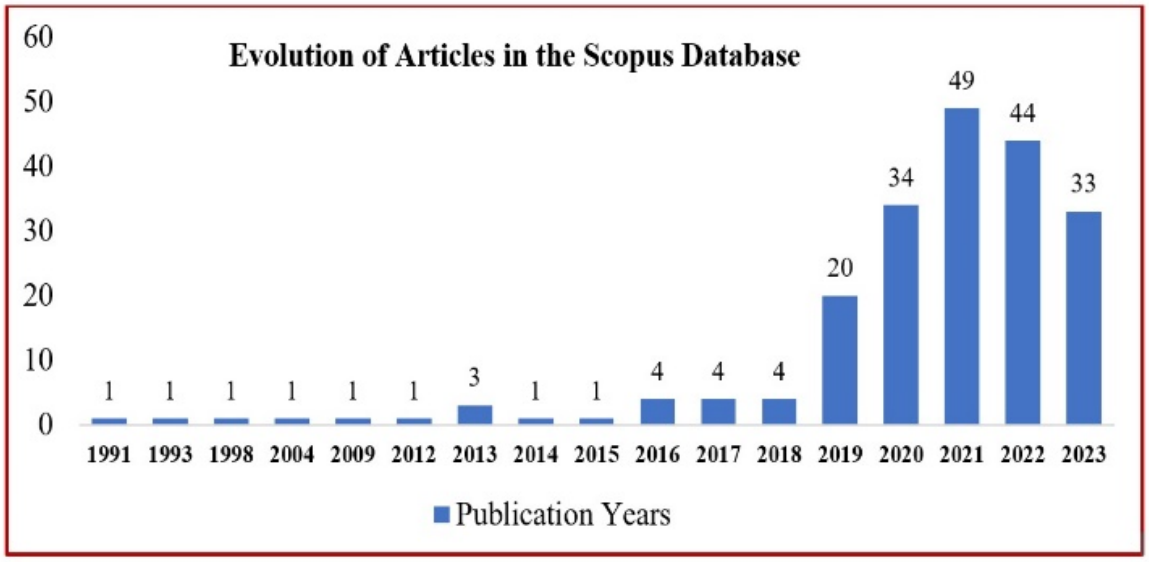
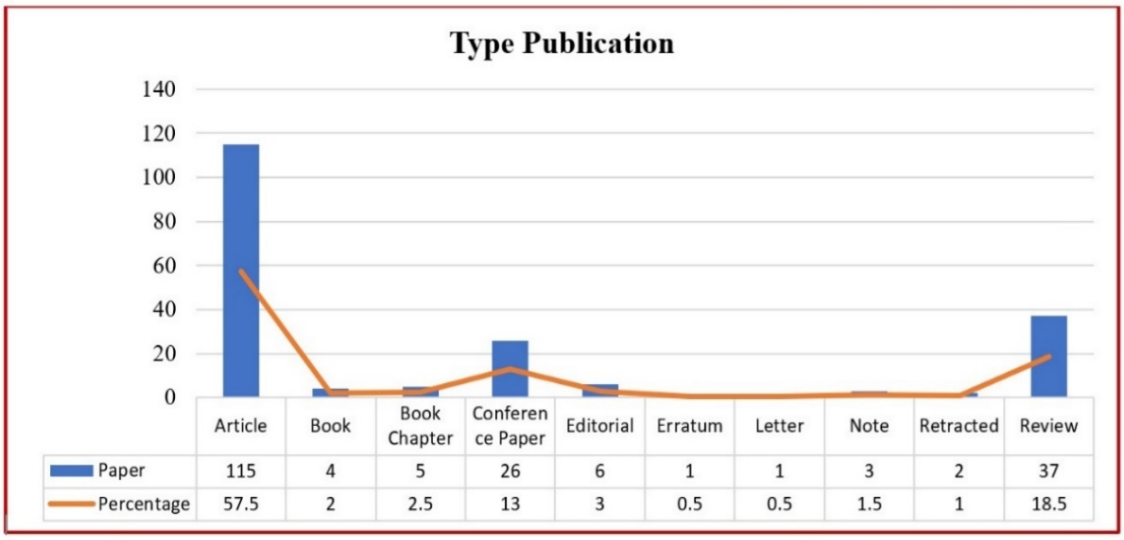


Figure 1. Graph showing how artificial intelligence has changed in educational publications from 1991 to 2023 using the Scopus database

The various study categories or publication types that have been conducted in the field of artificial intelligence (AI) in education are listed in Figure 4, along with the proportion of the 200 total papers that fall into each category. Articles are the most commonly published form of content, with 115 articles published at a rate of 57.5%. Articles are the main publishing type and seem to be the focus of study on the subject of artificial intelligence in education.

Next, at 37 (18.5%) points, is the review. The review includes a comprehensive analysis of the research and advancements in the field of artificial intelligence in education.

Book form number four, with a proportion of 2%. Books are a more comprehensive and condensed type of publishing (Figure 2). Books, while comparatively few in quantity, can have a major impact. Five book chapters made up a percentage of 2.5 percent. Articles that have been collected into books are called book chapters. Meeting paper in the range of 26–13%. Up to six editorials (3%). Error up to one (0.5%) percent. A repair or correction of errors that may have appeared in earlier publications is called an erratum. Letter up to one (0.5%). Retracted as many as two (1%), and noted as many as three (1.5%).



	Article	Book	Book Chapter	Conference Paper	Editorial	Erratum	Letter	Note	Retracted	Review
Paper	115	4	5	26	6	1	1	3	2	37
Percentage	57.5	2	2.5	13	3	0.5	0.5	1.5	1	18.5

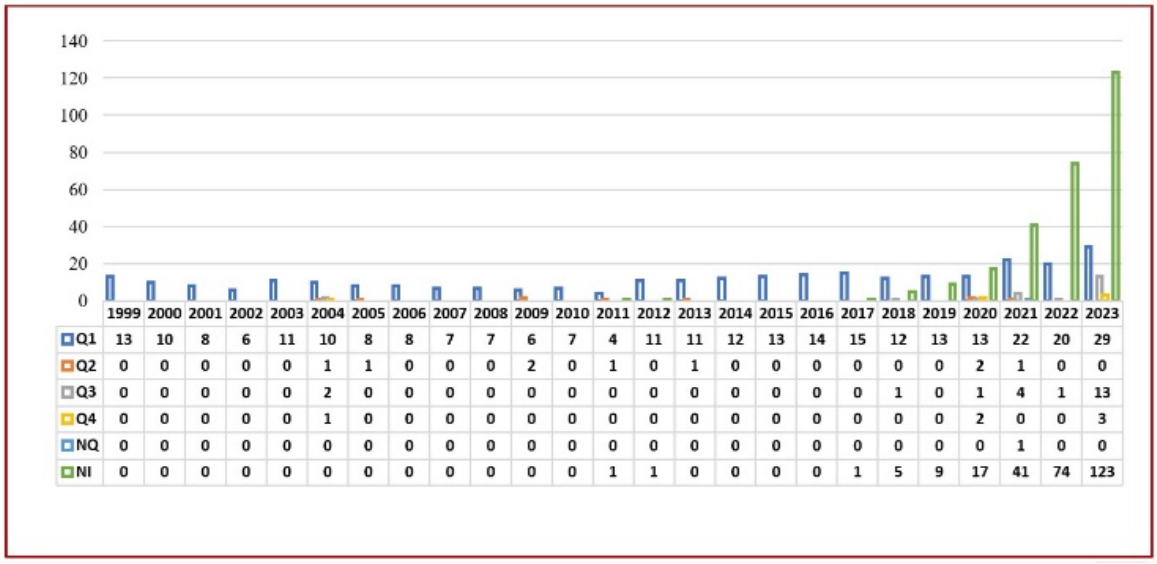
Figure 2. Type of publication

Figure 3 and Figure 4 present the overall statistics and percentages of the 600 articles that were discovered through the search results produced by the SEforRA tool.

These articles include information on the Scopus Journal Rank (SJR) ranking of journals for every year from 1999 to 2023.

The majority of journals fall into the highest category in terms of influence and impact, as seen by the comparatively high 48.33% of journals in the Q1 (high) quartile. With a lower distribution in these categories, the percentage of journals in the Q2 (high) quartile is approximately 1.5%, the Q3 (middle) is approximately 3.67%, and the Q4 (low) is approximately 1%. 272 journals, or 45.33% of all journals evaluated, were classified as being outside of the quartiles (NQ and NI).

The number of journals with high SJR values has significantly increased in recent years, particularly between 2021 and 2023. Variations in journal categories and quartile distributions may be indicative of shifts in the composition and influence of journals within a certain subject over time.



	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Q1	13	10	8	6	11	10	8	8	7	7	6	7	4	11	11	12	13	14	15	12	13	13	22	20	29
Q2	0	0	0	0	0	1	1	0	0	0	2	0	1	0	1	0	0	0	0	0	0	2	1	0	0
Q3	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	4	1	13
Q4	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	3
NQ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
NI	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	5	9	17	41	74	123

Figure 3. Scimago journal ranking

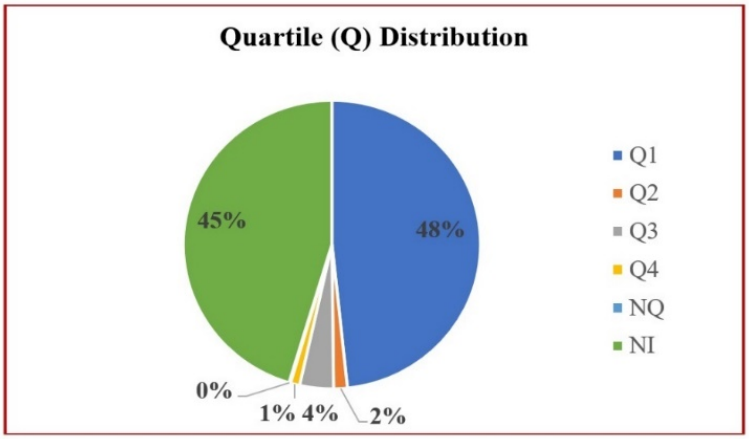


Figure 4. Using SEforRA tools, the quartile distribution diagram (Q) in Schimago (1999–2023)

3.2. Top Ten Ranking (Top 10)

The Top 10 artificial intelligence (AI) research projects in education are listed in Table 2. An explanation and interpretation of the table are provided below:

- O. Zawacki-Richter, ed. "Systematic review of research on artificial intelligence applications in higher education - where are the educators?". This systematic review assesses earlier studies on the use of AI in higher education. This article has a high impact and relevance with 621 citations.
- S.A.D. Popenici, author of "Exploring the Impact of Artificial Intelligence on Teaching and Learning in Higher Education". The impact of AI on teaching and learning in higher education is examined in this article. This article, which has 364 citations, significantly advances the knowledge of how artificial intelligence affects higher education.
- L. Chen, author of "Artificial Intelligence in Education: A Review". This paper, which was released in IEEE Access, offers a survey of AI in education. This article is a valuable resource in the literature on AI in education, with 341 citations.

- I. Rroll: "Evolution and Revolution in Artificial Intelligence in Education". With 263 citations, this paper from the International Journal of Artificial Intelligence in Education explores the development and evolution of AI in education.
- Hwang, G.J.: "Vision, challenges, roles and research issues of Artificial Intelligence in Education". This editorial, which has 246 citations, is taken from Computers and Education: Artificial Intelligence. It discusses the goals, difficulties, functions, and research questions of AI in education.

Table 2. Author, paper, journal, and citation are the top ten

No	Author	Title Paper	Citation	Year	Journal Publication	Type Publication
1	O. Zawacki-Richter	Systematic review of research on artificial intelligence applications in higher education – where are the educators?	621	2019	International Journal of Educational Technology in Higher Education	Review
2	S.A.D. Popenici	Exploring the impact of artificial intelligence on teaching and learning in higher education	364	2017	Research and Practice in Technology-Enhanced Learning	Article
3	L. Chen	Artificial Intelligence in Education: A Review	341	2020	IEEE Access	Review
4	I. Roll	Evolution and Revolution in Artificial Intelligence in Education	263	2016	International Journal of Artificial Intelligence in Education	Article
5	G.J. Hwang	Vision, challenges, roles, and research issues of Artificial Intelligence in Education	246	2020	Computers and Education: Artificial Intelligence	Editorial
6	X. Chen	Application and theory gaps during the rise of Artificial Intelligence in Education	226	2020	Computers and Education: Artificial Intelligence	Review
7	J.E. Aoun	Robot-proof: Higher education in the age of artificial intelligence	219	2017	Robot-Proof: Higher Education in the Age of Artificial Intelligence	Book
8	M. Chassignol	Artificial Intelligence trends in education: A narrative overview	206	2018	Procedia Computer Science	Conference Paper
9	G.J. Hwang	Definition, roles, and potential research issues of the metaverse in education: An artificial intelligence perspective	182	2022	Computers and Education: Artificial Intelligence	Article
10	M.J. Timms	Letting Artificial Intelligence in Education out of the Box: Educational Cobots and Smart Classrooms	178	2016	International Journal of Artificial Intelligence in Education	Article

3.3. Publications that Provide Research Articles on Artificial Intelligence in Education

Table 3. Journal name with the most citations

No	Journal Name	Number of Papers	Percentage	Total Citations	Percentage
1	Computers and Education: Artificial Intelligence	19	9.5%	1367	16.88%
2	International Journal of Educational Technology in Higher Education	4	2%	726	8.96%
3	International Journal of Artificial Intelligence in Education	4	2%	488	6.02%
4	IEEE Access	4	2%	429	5.29%
5	Research and Practice in Technology-Enhanced Learning	2	1%	372	4.59%
6	JMIR Medical Education	3	1.5%	268	3.30%
7	Education and Information Technologies	3	1.5%	263	3.24%
8	Procedia Computer Science	4	2%	254	3.13%
9	Robot-Proof: Higher Education in the Age of Artificial Intelligence	1	0.5%	219	2.70%
10	Sustainability (Switzerland)	7	3.5%	217	2.67%

Table 3 displays information on the journals that published articles on artificial intelligence in education research between 1991 and 2023.

Table 3 displays the journals that have received the most citations in the field of artificial intelligence (AI) in education. Computers and Artificial Intelligence in Education: This magazine ranks first with 19 articles or 16.88% of all the articles. It also has 1367 citations, which accounts for 16.88% of total citations. The International Journal of Educational Technology in Higher Education ranked second with 4 articles (2% of total papers) and 726 citations (8.96% of total citations).

There are 488 citations (6.03% of all citations) and 4 articles (2% of total articles) in the International Journal of Artificial Intelligence in Education. IEEE Access: This journal contains 4 articles (2% of total) and 429 citations (5.30% of total citations). Table 3 provides a summary of journals that significantly impact the scientific literature on artificial intelligence in education, based on the quantity of publications and citations acquired.

These journals may be the main source of references and the focus of attention on this topic.

4. Discussion

Examination of the results of co-word mapping, which involves utilizing keywords to identify noteworthy or unique terms present in specific publications, are derived from co-word analysis. In bibliometrics, knowledge mapping is a method for expressing a scientific field. For visualization, a landscape map with potential scientific subjects is made [39]. 60 terms associated with mobile learning and with at least two occurrences will be displayed by VOSviewer. Although VOSviewer will show 60% of the 60 terms by default [40], it is found from this investigation that all 100 terms will show up. Artificial intelligence (157), education (103), and application (16) are the terms that are most commonly utilized. Following the generation of keyword words, VOSviewer presents network visualizations based on these terms (Table 4).

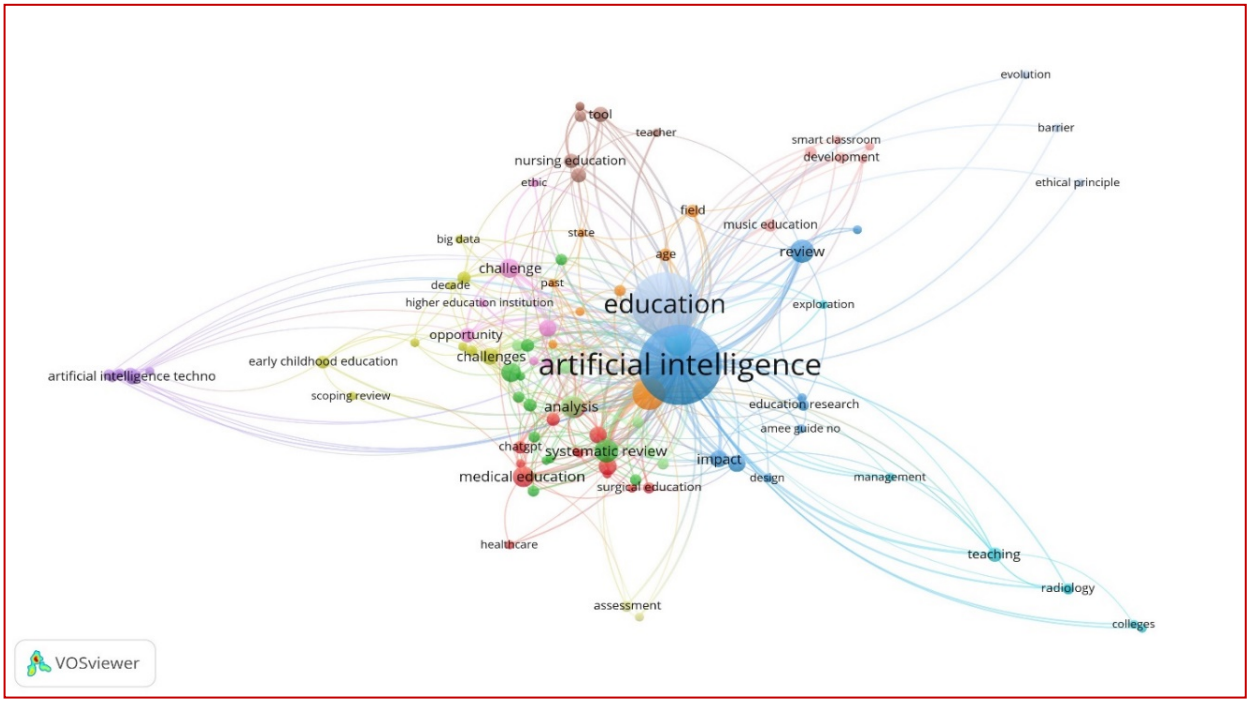


Figure 5. A map of research achievements in artificial intelligence for education using networks

The phrases and keywords used can be identified by mapping the data in Table 4, and then matching them with the information displayed in Figure 5 and Figure 6. The keyword term "education" is one example, appearing 103 times and having a light blue cluster color. The overlay and research density visualizations are displayed in addition to the artificial intelligence in education research development network visualization, and they can be explained as follows. In other words, it shows the history of research from year to year.

For instance, research with the keywords "tool, ethical principle, state, generative artificial intelligence, ChatGPT, and conversation" is bright yellow. The overlay visualization shows the year of publication of each article based on the keywords represented by the color gradation from dark blue to bright yellow. The articles authored by these six keywords were recent, having been published in the most recent year. It will complete a comprehensive analysis of each keyword indicated in yellow in the visualization overlay, keeping up with the most recent advancements in worldwide artificial intelligence in education research.

Table 4. Frequently used search phrases

No	term	occurrences	%	relevance score	No	term	occurrences	%	relevance score
1	abuse	2	0.30	2.98	51	future direction	4	0.55	0.55
2	academic progress	2	0.30	2.98	52	generative artificial intelligence	4	1.1	1.1
3	adoption	3	0.46	0.33	53	healthcare	2	0.35	0.35
4	age	4	0.61	0.38	54	higher education	25	0.19	0.19
5	aied	2	0.30	0.56	55	higher education institution	2	0.7	0.7
6	amee guide no	2	0.30	0.64	56	human	2	0.86	0.86
7	analysis	12	1.84	0.25	57	impact	7	0.23	0.23
8	analytic	3	0.46	0.26	58	implementation	3	0.84	0.84
9	application	16	2.45	0.15	59	implication	3	0.55	0.55
10	applications	4	0.61	0.78	60	innovation	4	2.19	2.19
11	artificial intelligence	157	24.1	0.1	61	insight	2	1.5	1.5
12	artificial intelligence application	3	0.46	0.69	62	language education	3	0.7	0.7

13	artificial intelligence education	9	1.38	1.63	63	machine learning	7	0.55	0.55
14	artificial intelligence learning	2	0.30	0.78	64	management	2	0.34	0.34
15	artificial intelligence method	2	0.30	5.39	65	medical education	11	0.38	0.38
16	artificial intelligence platform	3	0.46	2.36	66	medical education curriculum	2	0.79	0.79
17	artificial intelligence technologies	2	0.30	0.93	67	music education	4	0.47	0.47
18	artificial intelligence technology	5	0.76	2.97	68	need	4	0.35	0.35
19	assessment	3	0.46	0.31	69	new technology	2	0.44	0.44
20	barrier	2	0.30	0.19	70	nursing education	5	1.56	1.56
21	bibliometric study	2	0.30	0.6	71	ophthalmology	2	0.9	0.9
22	big data	2	0.30	0.33	72	opportunity	5	0.58	0.58
23	challenge	9	1.38	0.28	73	past	2	0.77	0.77
24	challenges	7	1.07	0.4	74	personalized education	2	1.25	1.25
25	change	2	0.30	0.78	75	physical education	4	3.66	3.66
26	chatgpt	4	0.61	0.64	76	practice	5	0.85	0.85
27	china	3	0.46	1.1	77	precision education	2	1.43	1.43
28	classroom	2	0.30	0.95	78	radiology	3	1.15	1.15
29	college	2	0.30	4.06	79	radiology education	2	1.01	1.01
30	colleges	2	0.30	2.11	80	reform	3	3.9	3.9
31	competency	3	0.46	1.73	81	research	8	0.3	0.3
32	construction	2	0.30	2.36	82	research trend	3	0.45	0.45
33	conversation	2	0.30	0.74	83	review	13	0.26	0.26
34	curriculum design	2	0.30	1.64	84	role	11	0.3	0.3
35	decade	2	0.30	0.37	85	roles	3	0.56	0.56
36	design	2	0.30	0.53	86	scoping review	2	0.88	0.88
37	development	3	0.46	0.67	87	smart classroom	2	0.58	0.58
38	discourse	2	0.30	0.57	88	special education	2	0.67	0.67
39	early childhood education	4	0.61	1.27	89	state	2	0.75	0.75
40	education	103	15.8	0.11	90	student	4	0.71	0.71
41	education research	3	0.46	0.69	91	surgical education	3	0.89	0.89
42	effectiveness	2	0.30	5.39	92	systematic literature review	3	0.84	0.84
43	era	7	1.07	0.38	93	systematic review	13	0.31	0.31
44	ethic	2	0.30	0.38	94	teacher	2	0.42	0.42
45	ethical principle	2	0.30	0.19	95	teaching	5	0.52	0.52
46	evolution	2	0.30	0.19	96	tertiary education	2	1.57	1.57
47	exploration	2	0.30	0.19	97	tool	6	1.22	1.22
48	feedback	2	0.30	0.28	98	university	3	2.43	2.43
49	field	4	0.61	0.42	99	use	7	0.46	0.46
50	future	3	0.46	0.51	100	virtual reality	2	1.21	1.21

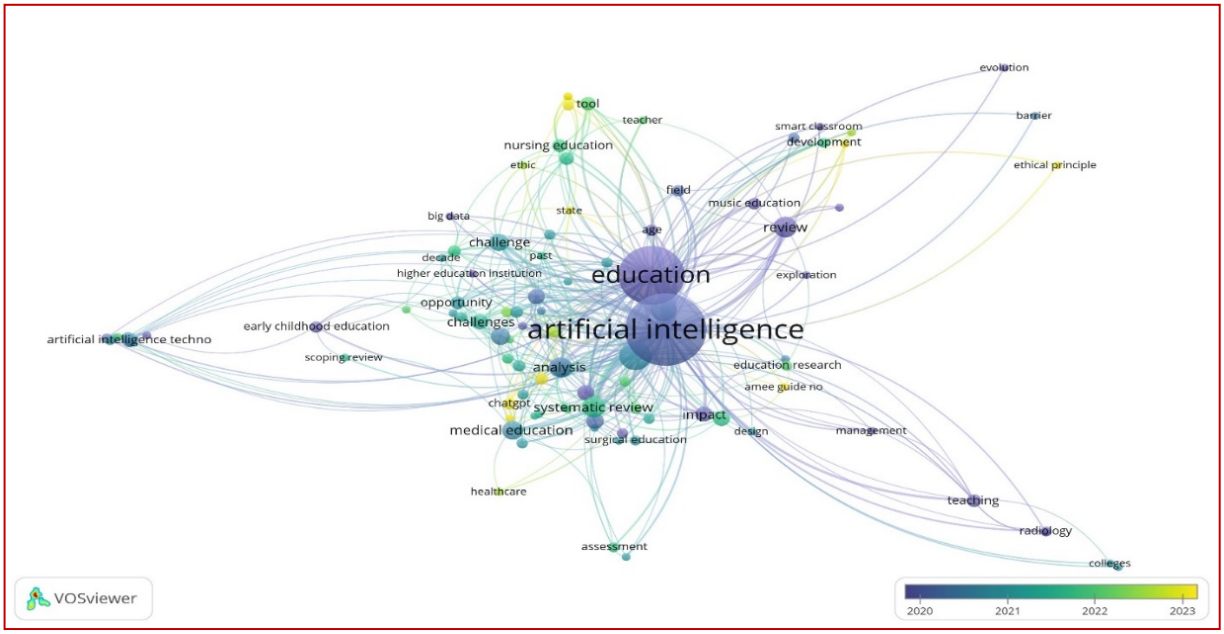


Figure 6. Overlay visualization

Based on Table 4 data on frequent and infrequent keywords in research on Artificial Intelligence in Education, some elements of novelty in this literature can be identified:

- Dominance of artificial intelligence: The term "Artificial Intelligence" is most prevalent, occurring at a rate of 24.1%. This implies that the role and use of artificial intelligence in education are particularly highlighted in this work. The majority of the literature centers on artificial intelligence (AI), emphasizing the topic's persistence and applicability throughout the literature on AI in education.
- Importance of the Connection to Education: The relevance of the connection between artificial intelligence and education is highlighted by the 103 instances of the term "education" (15.8%). This demonstrates that research tends to concentrate on both the technological aspects of AI and how it may be used in educational settings. This link demonstrates the applicability and influence of AI in altering the paradigm of education.
- Emphasis on Applications of AI The frequency of "applications" (2.45%), while not as high as the primary keywords, suggests a concentration on the use of AI in education. This shows that the literature makes an effort to investigate and talk about practical applications of AI technology in the context of education.
- Analysis of AI Implementation and Impact: The keyword "analysis" appears 1.84% of the time, indicating that in addition to introducing concepts or applications, this literature also offers assessments of AI's implementation and effects in education. This gives the research an evaluative perspective, which adds value.

Difficulties in AI Adoption: The term "challenge" appears 1.38% of the time, suggesting that people are aware of the difficulties or obstacles associated with implementing AI in the classroom. This demonstrates that the literature examines the limitations and obstacles that could appear throughout the implementation process in addition to the advantages.

Meanwhile, the following justifies the current directions in artificial intelligence research in education: The main pattern that protrudes is the predominance of "Artificial Intelligence" (24.1%) in the literature on AI in education. This aligns with the main research focus, which is the application, development, and impact of artificial intelligence in the educational setting. The phrase "education" has become more popular (15.8%), indicating the strong correlation between AI and education. This trend suggests that, in addition to its technical aspects, the literature focuses on how artificial intelligence (AI) can be utilized to enhance teaching and learning.

Although not particularly high, the frequency of "applications" (2.45%) indicates a propensity to understand and discuss the application of AI in educational contexts. This suggests an interest in finding out more about the real-world uses of AI in educational settings. The keyword "analysis" (1.84%) indicates a tendency of studies into the use and impact of AI in education. This pattern emphasizes how important it is to assess these technologies' use and implications for education cautiously. The rise of "challenge" (1.38%) shows a trend that suggests concerns about obstacles or hurdles to implementing AI in education. This shows that the implementation process is aware of its complexities and potential roadblocks.

The trend of concentrating on AI applications, particularly in the context of education is shown in the word "AI in education" (1.38%). This study probably aims to offer comprehensive insights into the different ways that artificial intelligence might improve the learning process. The keyword "Artificial Intelligence method" (0.30%) has a high relevance score (5.39%) despite its occasional use. This suggests a tendency that when the topic of applying AI in education is discussed, it is given significant importance. The methodological issues of using artificial intelligence in education may be the focus of future research. The trend of "effectiveness" (0.46%) with a high relevance score (5.39%) suggests that the literature frequently discusses how useful artificial intelligence is in the classroom. This emphasizes how crucial it is to comprehend the technology's efficacy in an educational setting in addition to using it.

With a high relevance score of 3.66 percent, the focus on "physical education" (0.30%) indicates a particular trend to look into the use of AI in the subject of physical education. This could be regarded as a novel and cutting-edge field of study where technology is used. The trend of "innovation" (0.30%) with a high relevance score (2.19%) suggests that research on the topic of how AI can be inventive in the classroom is a common theme in the literature. This draws attention to the possibility of coming up with fresh and, original ideas in this field.

Figure 7 displays the density visualization of the VOSviewer analysis results for artificial intelligence in education. The intensity or density of research groups is depicted by density visualization. Density can be used as a foundation to observe that there is still little research on the subject. On the other hand, if the color turns brilliant yellow, it means that the subject matter has been covered a lot and a lot. The fewer studies that have been done, the more faded or fuzzy the color that specifies the topic's phrase or term. The example in Figure 7—"evolution, barrier, ethical principle, teacher, healthcare, assessment, exploration, and colleges"—is a subject that has not received enough attention. The foundation color in these eight themes is extremely light and hardly perceptible.

Topics with the keywords: "education, artificial intelligence, analysis, ChatGPT, systematic review, medical education, surgical education review, and tool", are topics with a bright yellow color indicating that the topics in these keywords are themes that have experienced saturation of studies or have been frequently researched. However, topics with the keywords: evolution, barrier, ethical principle, teacher, healthcare, assessment, exploration, and colleges have the potential to produce high novelty if collaboration between keywords is carried out in conducting research.

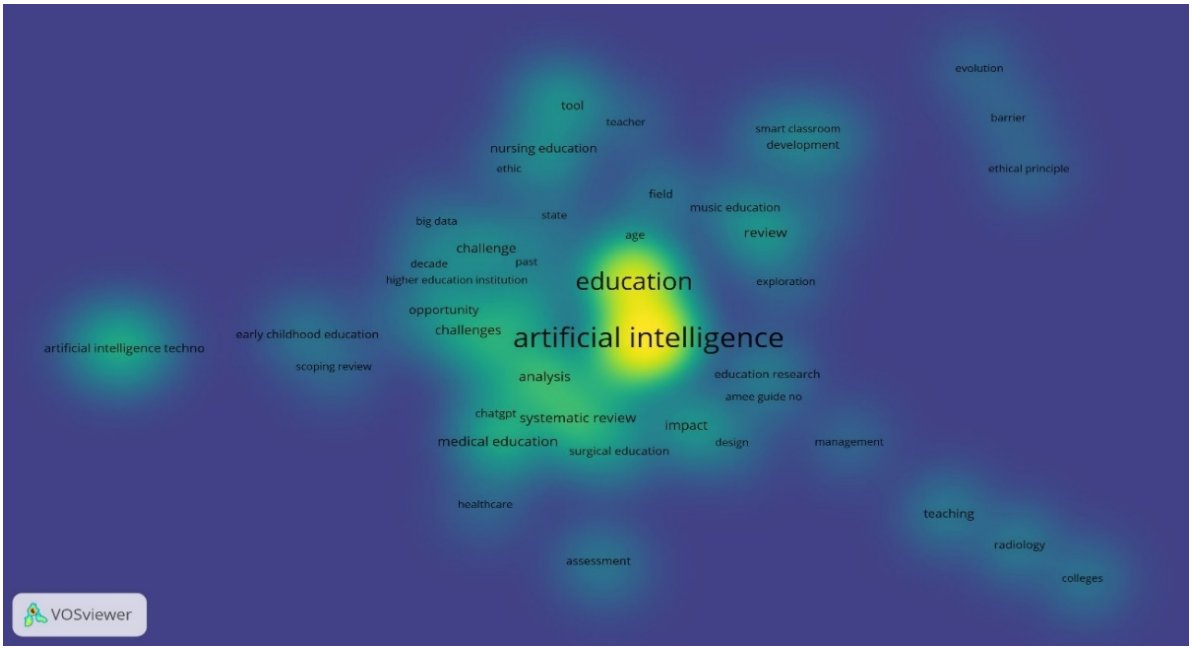


Figure 7. The density visualization

5. Conclusion

On the Scopus database, there was a general upward trend in the advancement of AI in education research beginning in 2018 and ending in 2021.

The progression of article development from the Scopus database from 1991 to 2023 was analyzed by the Artificial Intelligence in education research, with Scimago JR placing among the top 10 journals (author, journal name, article title, and article citation). Co-word analysis is one of the bibliometric analyses that can be seen using VOSviewer. Bibliometric analyses offer a summary and recommendations for additional study.

The amount of study in numerous areas about artificial intelligence (AI) in education is demonstrated by the density visualization produced by VOSviewer. The subjects "education, artificial intelligence, analysis, ChatGPT, systematic review, medical education, surgical education review, and tools" are those that have been the subject of a lot of research and are nearing research saturation. The terms "evolution, barrier, ethical principle, teacher, healthcare, assessment, exploration, and colleges" on the other hand, refer to subjects that have not gotten enough research attention.

However, if keywords cooperate when doing research, there may be a chance to produce a high level of uniqueness. The primary finding emphasizes the necessity of cross-topic cooperation to boost the uniqueness of research. If collaboration between topics is improved, understudied or underappreciated subjects, such as evolution, barriers, ethical principles, instructors, healthcare, evaluation, exploration, and higher education, have the potential to make important contributions.

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