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Artificial intelligence in higher-level education: A SWOT analysis and 20-year bibliometric analysis using VOSviewer

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Abstract

Artificial intelligence (AI) is transforming the domain of higher education. A bibliometric study about this is important, especially in identifying trends and gaps that are crucial for policy development, higher education management, and future research initiatives. The two-decade analysis provided an overview of the increasing trajectory of research publications concerning artificial intelligence in higher education. This research analyzed the 5522 searched articles in the Scopus database using bibliographic analysis following a systematic approach to data collection called PRISMA. This research shows that China and the United States emerged as the leading countries in terms of publication count. Likewise, the United States, China, India, and the United Kingdom demonstrate higher levels of collaboration compared to other countries. The majority of research articles predominantly use the English language. These findings mean that AI is gaining significant popularity in the higher education sector. It is likely influencing the teaching and learning pedagogies. The VOSviewer software was used to visualize global collaboration of documents, the co-occurrence of keywords, and the co-authorships. Some of the most used keywords were also identified in this study, like "Artificial Intelligence," "Higher Education," "Students," "High Education," and "Education." Moreover, this paper presented the SWOT analysis of the most cited papers.

Keywords: AI, Artificial intelligence, Bibliometric analysis, ChatGPT, Higher education, Microsoft Excel, VOSviewer

1. Introduction

The technology has transformed the landscape of education by enhancing teaching and learning methodologies, research paradigms, and governance mechanisms [1, 2]. Advanced technology like artificial intelligence (AI) enhances experiential learning, promotes personalized education, and improves employability by equipping students with industry-relevant skills [3]. Artificial intelligence, or AI, is a field within computer science that is more focused on application development that usually requires human intelligence. Similarly, artificial intelligence mimics human intelligence through the use of computer systems and machines programmed for specific tasks [4, 5]. Also, it encompasses the architecture of computers like robots that emulate aspects of human intelligence, such as the ability to learn, the ability to understand, and the ability to solve problems [6].

Higher-level education is a postsecondary education that encompasses institutions like universities and colleges that provide advanced learning opportunities [7]. Higher education represents several components like research endeavors, community engagement, and the development of highly skilled professionals [8-10]. It constitutes an essential element of societal progress for promoting intellectual engagement and innovation. This sector is cardinal in the development of several countries, where it supports economic advancement through education, research, and innovation [11].

The application of artificial intelligence in the realm of higher education is cardinal, especially in transforming the teaching and learning methodologies. Artificial intelligence enhances teaching and learning by personalizing learning materials to meet the needs of the students, thereby improving performance and motivation [12, 13]. It significantly enhances teaching and learning by optimizing instructional effectiveness and improving language proficiency [14]. It also enhances educational experience by personalizing or customizing learning for the learners, i.e., the students, and the educators in general [15-17].

The primary objective of this research endeavor was to describe the trends in scholarly publication from the year 2004 to 2024 pertaining to artificial intelligence in higher-level education, utilizing a research method called bibliometric analysis. The 20-year analysis will give an overview and will suggest insights about the trajectory of research publications. Bibliometric analysis is a research method that uses data to examine scholarly written publications [18,19]. By investigating patterns in publication data, citation frequencies, co-occurrence of keywords, or how the keywords appear together in a document, co-authorship or the practice of more than one author working in a research paper, and the collaboration of authors or institutions, or countries.

Bibliometric analysis yields significant insights into the progression of knowledge, the influence of particular works, and the dynamics inherent in scientific communication [20]. This comprehensive synthesis may produce profound insights and could further inform prospective inquiries. Consequently, Section 2 of this research paper provides the methodology used in conducting the study. It shows the database used, data sources, criteria for selection, and analytical methodologies utilized. On the other hand, Section 3 shows the outcome of the bibliometric analysis. It illustrates the collected data through diverse tabular formats and graphical depictions, facilitating a better comprehension of publication trajectories, author contributions, and the frequency of keywords pertinent to the study's emphasis. Furthermore, Section 4 shows the discussion pertaining to the research findings or results. In here, the research findings are examined, interpreted, and visualized, emphasizing notable patterns, trends, and insights. Moreover, Section 5 encompasses the conclusion, which encapsulates the principal aspects of the study, reiterates its contributions, and underscores the implications of the results.

2. Research method

2.1. Data gathering procedures

In order to conduct an in-depth and comprehensive examination of scholarly articles and published papers that pertain specifically to the use of artificial intelligence in higher education, a favorable consideration is given to a database with a wide coverage, citation metrics, and exportable datasets. These factors have led to the selection of the Scopus database. Scopus, a globally recognized bibliographic database, was used by the researcher for this bibliometrics research [21, 22].

2.2. Inclusion and exclusion criteria

The following inclusion criteria were set in order to filter the search results:

- Publications related to artificial intelligence and higher education referring to research titles, detailed abstracts, and pertinent keywords, all of which were utilized in the formulation of the query (TITLE-ABS-KEY (artificial AND intelligence) AND TITLE-ABS-KEY (higher AND education)),
- Publication year was set to 2004-2024. and
- Published papers using any language.

The following exclusion criteria were set in order to filter the search results:

- Publications not related to artificial intelligence and higher education.
- Conference proceedings; and
- Papers published outside the specified time frame.

2.3. Data extraction procedures

This research is focused on identifying research articles about AI in the realm of higher-level education. The query in the Scopus database was done on 15 April 2025. The search criteria include research titles, abstracts, and keywords. The following collection of terms was used in this study: “artificial intelligence” and “higher education”. The search query yielded a total of 5793 scholarly articles. Upon the implementation of the filter, the retrieved articles were reduced to 5788. These publications were subsequently exported and downloaded using CSV format.

The dataset was initially processed using a spreadsheet called Microsoft Excel to do data cleaning and to remove items with erroneous or incomplete information. The scholarly manuscript meticulously incorporates the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, thereby ensuring that a thoroughly systematic and methodical approach is applied throughout its comprehensive bibliometric analysis, which is crucial for the rigor of academic research [23].

2.4. Data processing and cleaning

These academic publications were then systematically exported and downloaded in a CSV file format for further analysis. The initial stage of the dataset processing was conducted using a software application known as Microsoft Excel, which facilitated the essential data cleansing process aimed at eliminating any entries that contained erroneous or incomplete information. Following the data cleansing procedure, the number of scholarly articles decreased to 5552.

2.5. Data presentation

VOSviewer is a sophisticated software application that is usually used in the analysis of bibliometric data, leading to the visualization and construction of network maps pertaining to academic publications [24, 25]. This software plays a cardinal role in mapping the interconnections between keywords and authors within the searched scholarly articles. The search results for this research were analyzed using the VOSviewer software with version number 1.6.20.

This research aims to answer the following questions:

R1. What are the two-decade annual publication trends from 2004 to 2024?
R2. Which countries have the most publications?
R3. How is the global collaboration of the documents published per country?
R4. What are the highly cited articles?
R5. What are the advantages and disadvantages of using SWOT?
R6. What languages are used in the publications?
R7. What are the types of documents used in the publications?
R8. What are the common subject areas in the searched articles?
R9. What are the common keywords used in the searched articles?
R10. What is the collaboration network in terms of co-authorship?

3. Results

Figure 1 shows the data collection and analysis. Consequently, Figure 2 shows the trends in annual publication for two decades. 2004 started with 7 publications and 2024 has now 2411 publications. This is approximately equivalent to a 34,000% increase. The presented graph was done using Microsoft Excel.

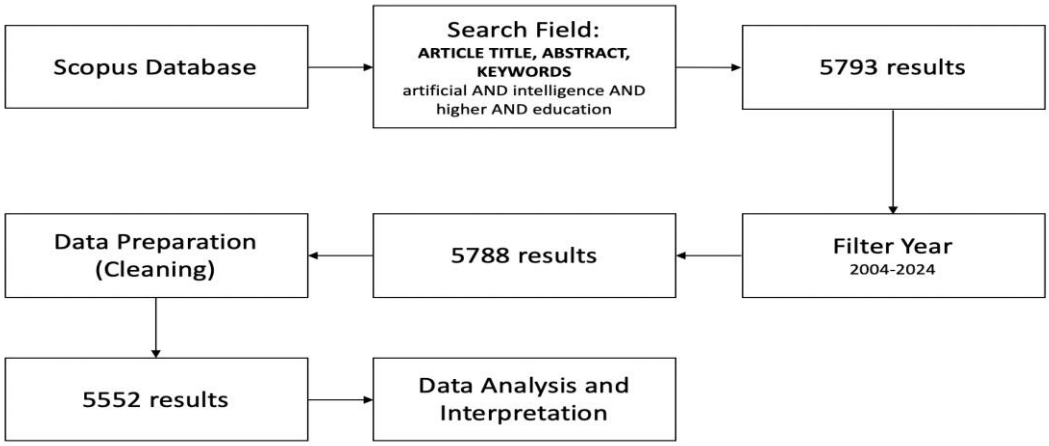

Figure 1. Data collection and analysis

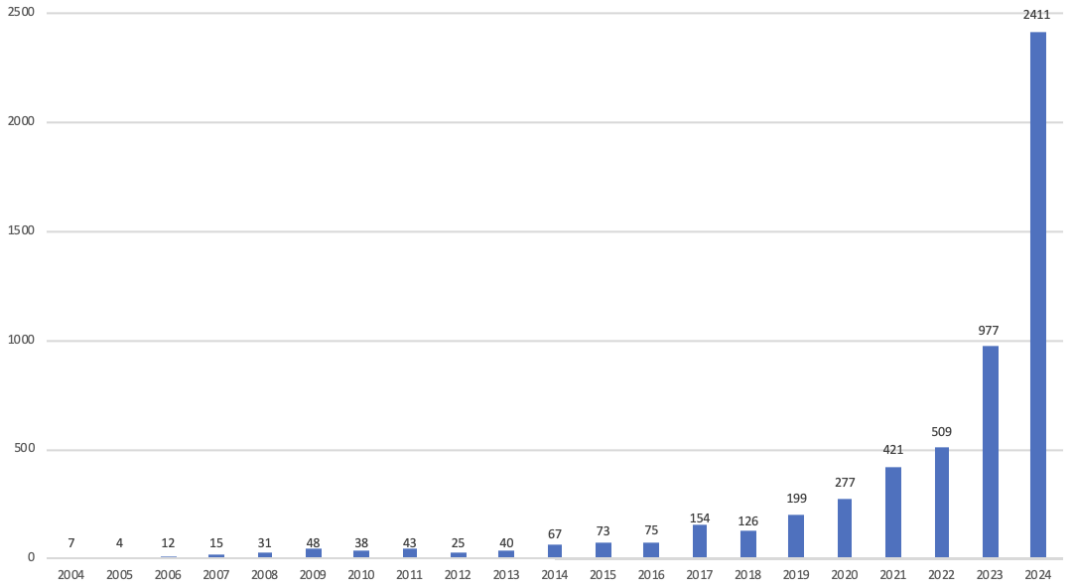

Figure 2. Annual publication trend

Figure 3, on the other hand, shows the leading countries in terms of the number of publications. Identifying the top is crucial for understanding global research dynamics [26]. China having 1007 paper publications, followed by the US with 855 number of publications, India with 397 number of publications, United Kingdom with 348, Spain with 271 number of publications, Australia with 235, Germany with 194 number of publications, Mexico with 168, Saudi Arabia with 157, and Russian Federation with 150 number of publications respectively. The presented graph was done using Microsoft Excel.

Figure 3. The top countries with high publication count

Figure 4 shows the collaboration or the interconnection of the different countries. Using VOSviewer, the following thresholds were set: the number of documents per country is 5, and the number of citations per country is 2 [27, 28]. 93 countries in total out of the 185 met the set thresholds.

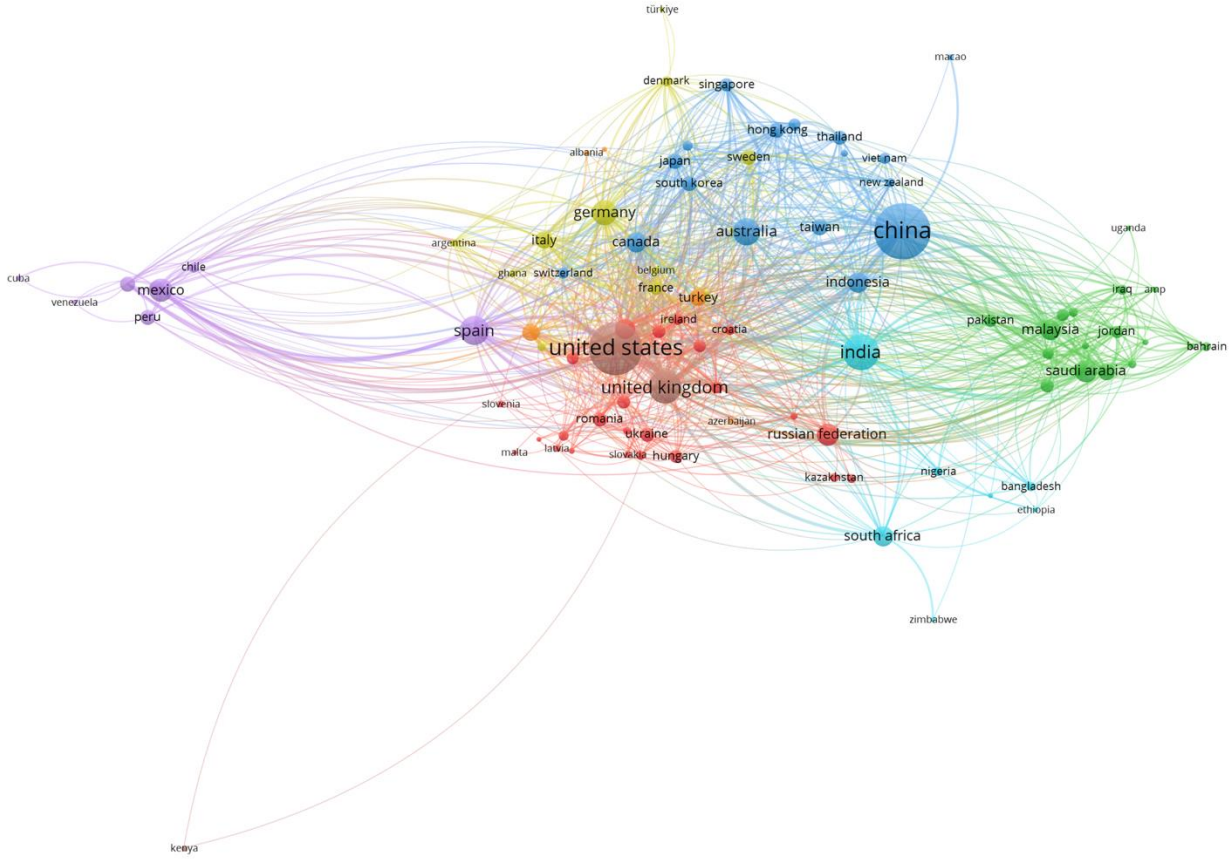

Figure 4. Global collaboration through documents published by the country

Table 1 shows the top ten articles in terms of the number of citations. The article titled "Systematic review of research on artificial intelligence applications in higher education – where are the educators?" got the most citations and is ranked number 1. The authors of this article are Olaf Zawacki-Richter, Victoria I. Marín, Melissa Bond, and Franziska Gouverneur. Rank number 2 goes to the article titled "Artificial Intelligence in Education: A Review". The authors are Lijia Chen, Pingping Chen, and Zhijian Lin. Rank number 3 goes to the article titled "Tensor Decomposition for Signal Processing and Machine Learning". The authors are Nicholas D. Sidiropoulos, Lieven De Lathauwer, Xiao Fu, Kejun Huang, Evangelos E. Papalexakis, and Christos Faloutsos. Moreover, the top three journals based on the citation count are "International Journal of Educational Technology in Higher Education", "IEEE Access", and "IEEE Transactions on Signal Processing".

Table 1. Research articles with the most citation count

Rank	Journal	Article Title	Authors	Year	Citations	Ref
1	International Journal of Educational Technology in Higher Education	Systematic review of research on artificial intelligence applications in higher education – where are the educators?	Zawacki-Richter et al.	2019	1761	[29]
2	IEEE Access	Artificial Intelligence in Education: A Review	Chen L. et al.	2020	1382	[30]

Rank	Journal	Article Title	Authors	Year	Citations	Ref
3	IEEE Transactions on Signal Processing	Tensor Decomposition for Signal Processing and Machine Learning	Sidiropoulos et al.	2017	1198	[31]
4	IEEE Access	Internet of things (IoT) for next-generation smart systems: A review of current challenges, future trends, and prospects for emerging 5G-IoT Scenarios	Shafique et al.	2020	1008	[32]
5	Journal of Applied Learning and Teaching	ChatGPT: Bullshit spewer or the end of traditional assessments in higher education?	Rudolph et al.	2023	868	[33]
6	Neurocomputing	Identification of rice diseases using deep convolutional neural networks	Lu et al.	2017	856	[34]
7	Innovations in Education and Teaching International	Chatting and cheating: Ensuring academic integrity in the era of ChatGPT	Cotton et al.	2024	849	[35]
8	Technology-Enhanced	Exploring the impact of artificial intelligence on teaching and learning in higher education	Popenici and Kerr	2017	767	[36]
9	European Radiology Experimental	Artificial intelligence in medical imaging: threat or opportunity? Radiologists are again at the forefront of innovation in medicine.	Pesapane et al.	2018	540	[37]
10	Innovations in Education and Teaching International	A SWOT analysis of ChatGPT: Implications for educational practice and research	Farrokhnia et al.	2024	471	[38]

Also, in Table 1, two articles were published in the year 2024. One article was published in 2023. Two articles were published in 2020. One article was published in 2019. One article was published in 2018. Three articles were published in 2019.

Figure 5, on the other hand, shows the common languages used in the publication of documents. It is clear that the English language is the dominant language accounting to 5333 documents or 96% of the total published papers, followed by 104 documents which were written in Spanish, 44 documents were written in Chinese, 41 documents were written in Russian, 13 documents were written in Portuguese, 4 documents each for German and Japanese languages, 3 for the Turkish language, 2 documents each for Hungarian and Slovenian languages, and 1 document each for both Korean and Persian languages. The figure distinctly illustrates the popularity of the English language in research publications pertaining to artificial intelligence in higher education. Researchers who aspire to achieve a more extensive impact frequently select English as their medium to engage with global journals, conferences, and academic audiences [39].

Table 2, on the other hand, shows the strengths, weaknesses, opportunities, and threats. The data gathered came from the searched articles found in Table 1. They are ranked based on how frequently they appeared among the top papers with high citations. According to the top documents, the advantages of artificial intelligence in the realms of higher education lie in its ability to enhance the learning experiences. It is evident that artificial

intelligence has improved the learning experience of both the educator and the learner in a plethora of ways. Through AI, learning can now be done anytime and anywhere, and it can also be done at a different pace depending on the student's learning capacity. Other advantages are improved learning assessments and evaluation, integration of predictive analytics, improved tutoring systems, efficient in administrative tasks, adaptable in terms of school expansion, improved decision-making because of the data, enhanced instructional quality, support for educators, and increased collaboration facilitation. Disadvantages, on the other hand, are more on data privacy, costing, ethical, and academic integrity issues. Opportunities are in research advancements, development of new pedagogical approaches, global learning opportunities are the ability to connect learners around the globe, and continuous improvement. Threats are more on the reliance of technology, inequity of access because of unequal access to resources like the internet, weakened quality of education, resistance to change, and rapid advancements of technology may lead to job displacement.

Table 2. SWOT analysis according to the highly cited documents

Rank	Strengths	Weaknesses	Opportunities	Threats
1	Enhance learning experiences [29] [30] [32] [33] [35] [36] [37] [38]	Issues in data privacy [29] [30] [31] [32] [37]	Research advancements [33] [34] [36] [38] Development of new pedagogical approaches [29] [36] [37] [38] Global learning opportunities [30] [31] [32] [37] Continuous improvement [30] [31] [32] [37]	Over reliance on technology [29] [30] [31] [32] [33] [36] [37] [38]
2	Efficiency for administrative tasks [29] [30] [31] [32] [36] [37]	Academic integrity issues [33] [35] [38] Ethical issues [29] [36] [37]	Innovative curriculum development [30] [32] [33]	Job displacement [29] [30] [31] [32] [33] [36] [37]
3	Efficient assessment and Evaluation [29] [33] [34] [35] [38]	Assessment challenges [35] [38] Bias in AI Algorithm [31] [38] Implementation cost [30] [31]	Enhance accessibility [33] [36]	Inequity of access [29] [30] [33] [36] Weaken quality of education [29] [32] [35] [37]
4	Data-driven insights [29] [31] [32] [37]	Integration challenges [29]		Ethical considerations [29] [32] [35]
5	Enhance instructional quality [30] [35] Scalability in education [29] [30]			Resistance to change [31] [36]

Rank	Strengths	Weaknesses	Opportunities	Threats
6	Intelligent tutoring systems [29] Increase collaboration facilitation [35] Predictive analytics [29] Support for educators [30]			

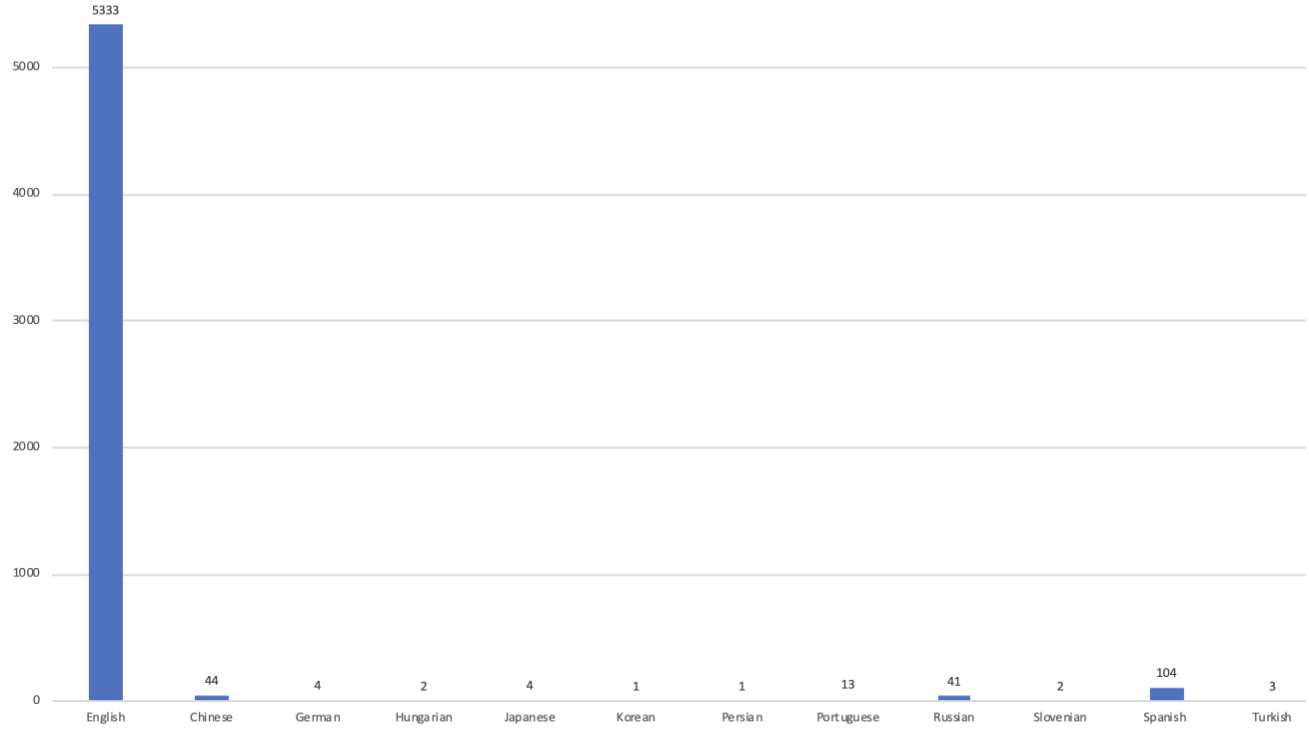

Figure 5. Language of publication documents

Figure 5, on the other hand, shows the languages used in the publication documents. It is evident that the English language is the dominant language accounting to 5333 documents or 96% of the total published papers, followed by 104 documents which were written in Spanish, 44 documents were written in Chinese, 41 documents were written in Russian, 13 documents were written in Portuguese, 4 documents each for German and Japanese languages, 3 for the Turkish language, 2 documents each for Hungarian and Slovenian languages, and 1 document each for both Korean and Persian languages. The figure distinctly illustrates the popularity of the English language in research publications pertaining to artificial intelligence in higher education. Researchers who aspire to achieve a more extensive impact frequently select English as their medium to engage with global journals, conferences, and academic audiences [39]. The presented graph was done using Microsoft Excel.

Figure 6 shows the categories of publication. Articles accounting for 2597 documents or 47% of the total publication documents. That is nearly half of the total, indicating that journal articles remain the dominant mode of scholarly communication. Conference papers with 2217 or 40% of the total publication documents. This is because presenting research at conferences allows for quicker feedback and community engagement. Book chapters follow distantly with 384 entries, showing that while still relevant, they're not the primary channel. It was then followed by a book with 384 pages. The rest of the documents were followed by review papers, a book, an editorial, a note, a letter, and a data paper, respectively. The presented graph was done using Microsoft Excel.

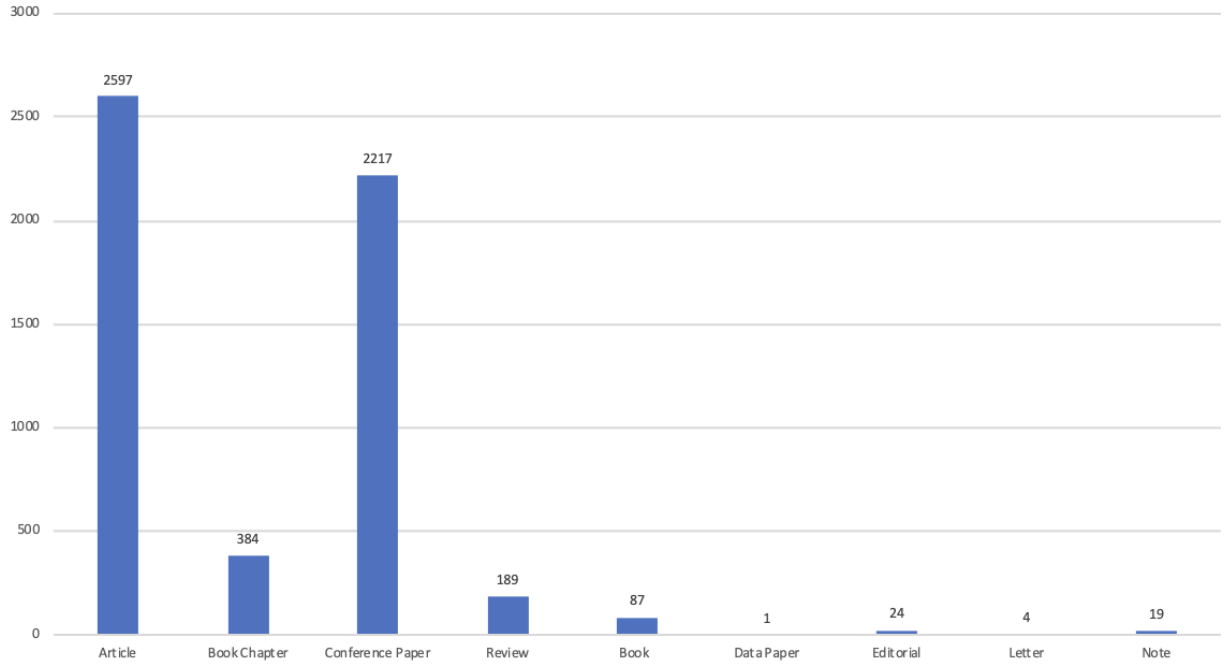

Figure 6. Categories of publication documents

Figure 6 shows that articles and conference papers are the most common categories of publication documents. This means that most authors prefer this category in order to disseminate research information. The number of documents in these two publications is quite far from the others. The presented graph was done using Microsoft Excel.

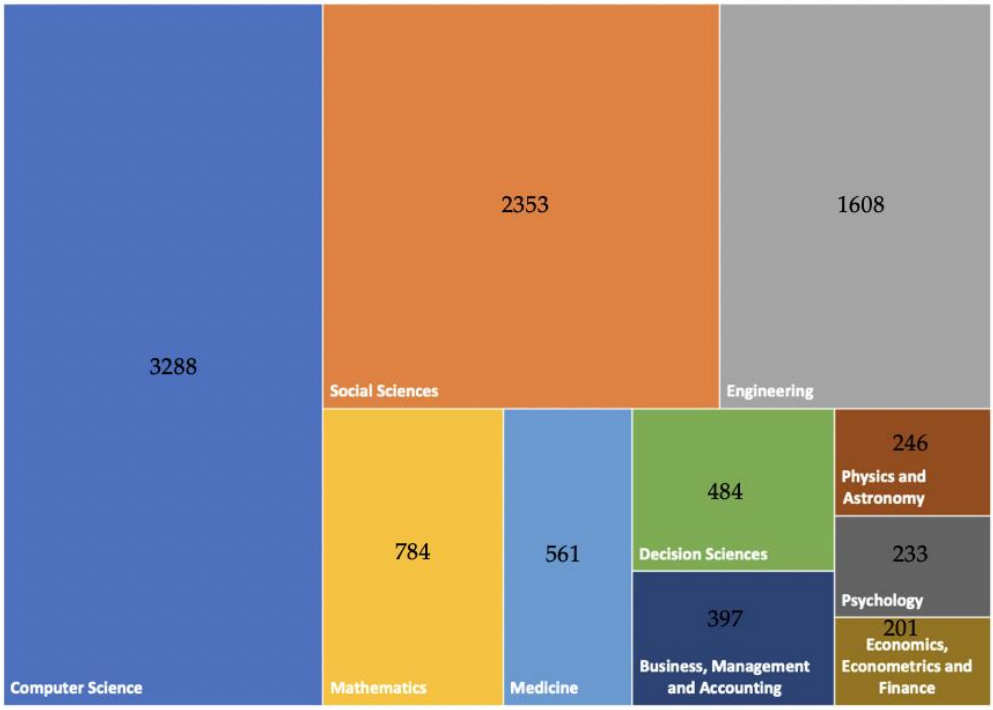

Figure 7. Top subject areas

Figure 7 shows the tree map of the searched documents in terms of subject areas [40]. The researcher utilized the tree map feature available in the charts section of Microsoft Excel to visually represent the data. It shows that computer sciences, social sciences, and engineering are the leading subject areas. The disparity with the other subject areas is quite high. For example, the subject area Engineering has a count of 1608 versus the subject area mathematics with only 784. The difference is more than double. Computer science is the topmost

subject area with a count of 3288, almost a thousand difference from social sciences. It only means that computer science is the most in-demand subject area over the past two decades.

Figure 8, on the other hand, shows the co-occurrence of keywords. VOSviewer was used to illustrate the relationship using this threshold: the minimum number of keyword occurrences is 25 [41, 42]. The following keywords, “artificial intelligence”, “higher education”, and “education” are found in the center of the figure. The three colored clusters are also evident: blue, red, and green. Education is also seen in the middle of the green cluster and red cluster, indicating a strong relationship. Ethics is seen in the blue cluster, but with a small size, only indicating that its relevance may not be as important as compared with the other keywords.

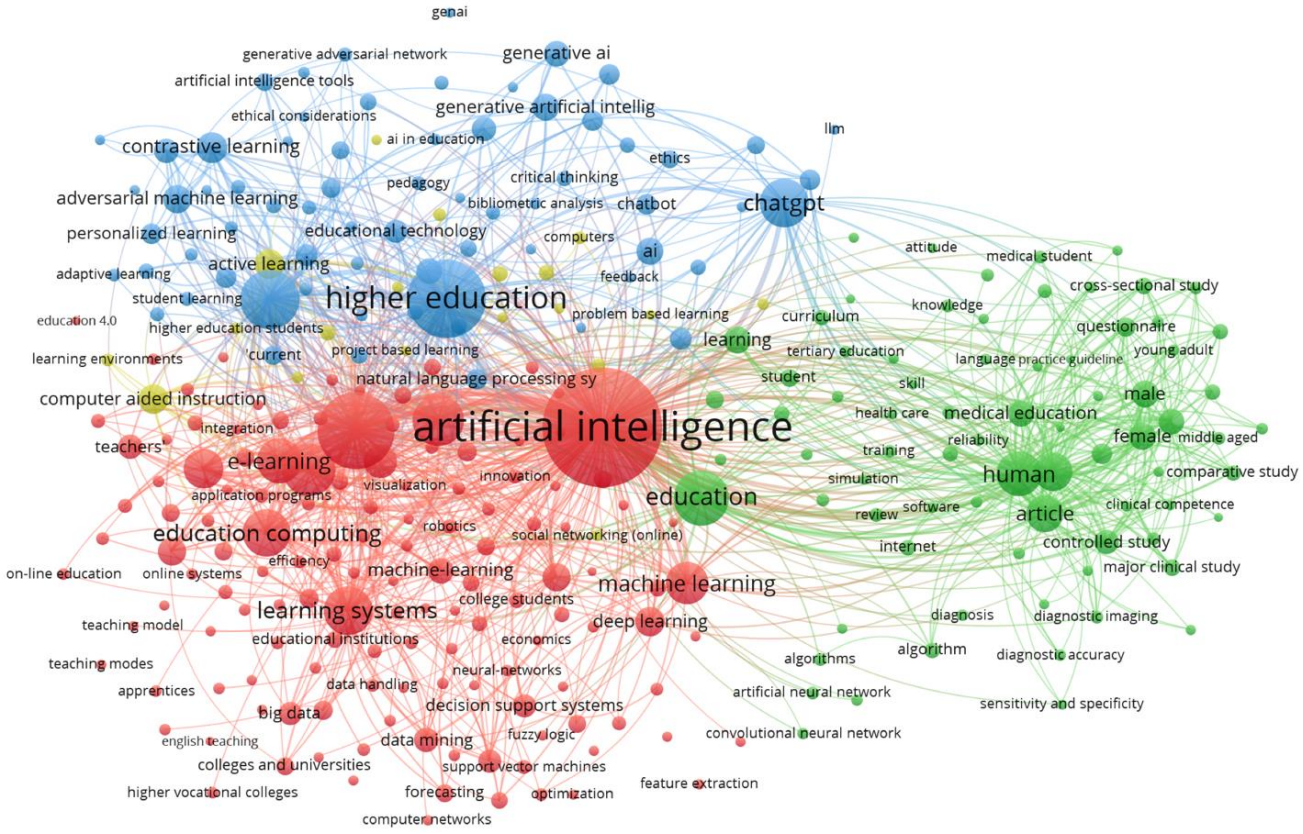

Figure 8. Co-occurrence of keywords

Table 2 shows the top 10 most-used keywords [43]. “Artificial Intelligence” tops the list. Artificial intelligence is transforming every sector, most especially the education sector. The close presence of terms like "Higher Education," "Students," and even "High Education" shows how much attention is being paid to artificial intelligence’s role in colleges and universities. The keyword “students” alone also indicates that the students play a big role in AI in higher education. Educators and other researchers alike are clearly trying to understand how tools like ChatGPT and other platforms fit into classrooms, support student learning. ChatGPT is the only large-language model that appeared on the most used keywords. This signifies that this tool is popular in higher education.

Table 2. Most adopted keywords

Rank	Keyword/s	Frequencies
1	Artificial Intelligence	3551
2	Higher Education	1526
3	Students	1493
4	High Education	881

Rank	Keyword/s	Frequencies
5	Education	774
6	Engineering	706
7	Teaching	684
8	Learning Systems	610
9	ChatGPT	586
10	Education Computing	563

Similarly, the word "Engineering" popping up in the top ten most used keywords suggests that artificial intelligence is becoming popular in this field.

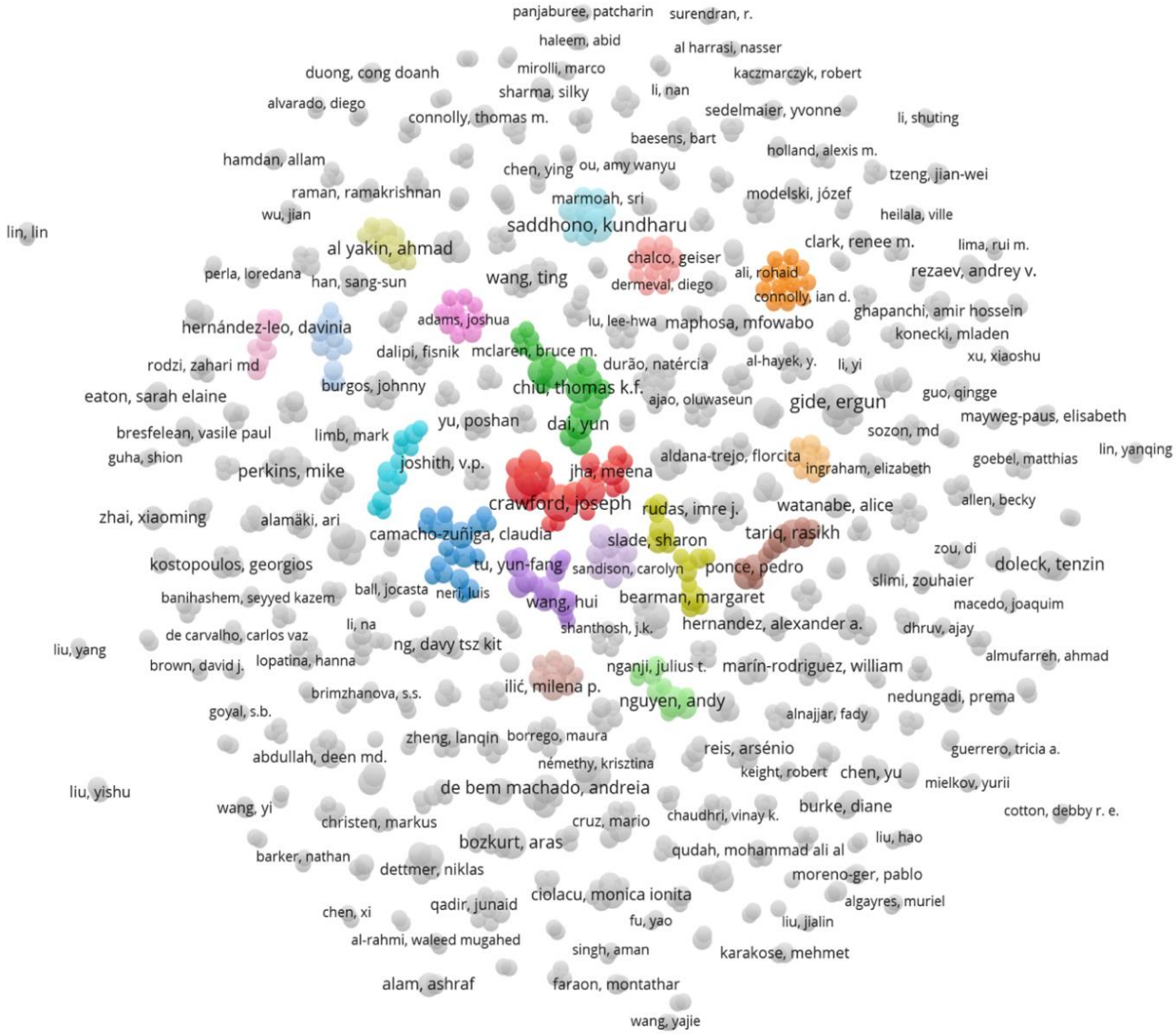

Figure 9. Co-authorship

Figure 9 shows the network of co-authorship using VOSviewer. The following thresholds were set: co-authorship for the analysis type, authors for the analysis unit, and full counting for the method of counting [44, 45]. This visualization shows a co-authorship network, mapping how researchers are connected based on shared publications. Each colored cluster represents a group of authors who tend to collaborate more closely with one another. At the center, we see a dense core of names like Crawford, Joseph, and Jra Mena, who appear to play central roles in linking different clusters, likely due to their broad collaborations across research groups. The

more central an author's name appears, the more connected they are within the scholarly community. On the outer edges, smaller clusters and isolated names imply either emerging researchers or those working in more specialized or independent areas.

4. Discussion

The two-decade scholarly publications spanning from the year 2004 to 2024 signify an increasing interest and an intensification of research endeavors. The data implies that recent years have experienced a notable increase in academic focus, likely propelled by the advent of emerging technologies and an augmented global relevance. The bibliometric study on the 5552 searched documents in the Scopus database in the last two decades shows a staggering 2411 publications in the year 2024 alone.

Another noteworthy aspect is that only a limited number of countries are actively engaged in the research domain concerning AI in higher education. This concentration may be attributed to the disparities in research resources such as funding, level of knowledge, or even the presence of technologies used in the countries. This underscores the need for global partnerships and more inclusive research endeavors, wherein emerging economies and institutions are encouraged to support other countries or institutions. Countries like China and the United States lead significantly in research publications. This scattering emphasizes the concentration of research activity in the technologically advanced and economically stronger regions, reflecting global disparities in research capabilities and resources. Figure 4 shows the global collaboration of documents by country. It is clear that countries like the United States, China, India, and the United Kingdom emerge as predominant players since they occupy a central position characterized by the largest nodes and the most substantial connection lines. The employed color scheme categorizes nations into clusters, indicating that certain countries engage in close collaborative efforts. The figure shows a strong interconnection among European nations, while Asian countries are similarly interlinked, particularly around the hubs of China and India. Latin American countries, including Mexico, Chile, and Peru, exhibit a somewhat distinct grouping yet maintain connections that extend toward larger collaborative networks. It is clear that the collaboration of different countries is seen in the figure. Additionally, the leadership in research collaboration is not solely attributed to major countries; rather, numerous smaller nations also give their research contributions. This leads to the consolidation of knowledge across the globe.

Additionally, the SWOT analysis revealed that AI in the realm of higher education enhances learning experiences, and issues in data privacy are the common strengths and weaknesses, respectively. Moreover, it shows that research advancements, development of new pedagogical approaches, global learning opportunities, and continuous improvement are opportunities, and over-reliance on technology is a threat.

Figure 8 shows the connections of artificial intelligence with the other keywords. Three colored clusters are evident: red, blue, and green. The giant red cluster in the middle shows how dominant topics like "artificial intelligence," "machine learning," "learning systems," "e-computing," and "education computing" are in recent research. The upper portion shows the blue cluster—it's heavily focused on "higher education", "active learning", "generative AI", and "ChatGPT". It's pretty evident that people are seriously exploring how AI tools are reshaping teaching and learning. On the right side is the green cluster. "Education", "medical education", "human", "medical student", and "healthcare" are the popular topics. This shows that the healthcare sector is also into artificial intelligence. It is also interesting to see how the keyword "ChatGPT" is isolated. This keyword is linked to several other keywords like "ai", "knowledge", "llm", "learning", "chatbot", and even "ethics." This is supported by the top ten most-used keywords. ChatGPT is the only AI tool that appeared on the list.

Figure 9 shows the network of co-authorship. This visualization highlights a network of researchers who appear to be working on related topics. It's clear that these authors are grouped based on their collaborative relationships in their publications. Names like Crawford, Joseph; Chiu, Thomas; and Camacho-Zuñiga, Claudia popped out at the center of their respective clusters, suggesting they play key roles, perhaps as lead authors or frequent collaborators in their areas.

5. Conclusions

Drawing from the visualizations using VOSviewer and the dataset using Scopus database, it is evident that scholarly publications show a significant growth in the last two decades. The increasing volume of published articles indicates a rising interest among the academic community.

It is clear that only a limited countries were involved in the research publications. These countries are the ones with the resources for research. This paper identified that China and the United States are the two prominent countries in research publications. These two, together with India, Spain, and the United Kingdom, have collaborated with other nations in terms of research. More than strengthening international relations, these collaborations allow different researchers to share resources and skills, leading to higher-quality papers and increasing global impact.

The research titled "Systematic review of research on artificial intelligence applications in higher education – where are the educators?" by authors Zawacki-Richter et al. in 2019 got 1761 citations. This means that this paper is high impact and has a global influence. Its relevance has been observed by many authors, which is why it has many citations.

The SWOT analysis revealed that the identified strengths can be used to take advantage of the opportunities and to mitigate the threats. The identified weaknesses, on the other hand, are an opportunity for the stakeholders, especially in higher levels of education, to improve.

The dominance of the English language in scholarly literature is observed. While this offers a degree of uniformity and facilitates global engagement, it can also unintentionally exclude valuable insights from non-English-speaking researchers. It is important to consider efforts that support language diversity.

Articles and conference papers are popular in the search results. This implies that these types of documents are easier to publish as compared to the other types.

Furthermore, computer science is distinctly identified as the predominant academic discipline, which is logical considering the technological underpinnings of artificial intelligence. This also opens avenues for interdisciplinary collaboration.

In terms of the most used keywords, it is also surprising that the keyword "ethics" did not appear in the top ten. It is alarming to say that large-language models such as ChatGPT may be exploited unethically.

In conclusion, the research landscape in the fields of AI and higher education is both active and growing. The active and growing number of scholarly publications serves as a favorable indicator that the academic community is recognizing and engaging with the opportunities. The findings also highlight areas necessitating increased focus, such as linguistic inclusivity, broader representation of countries, and interdisciplinary collaboration. Future studies can be improved by including other scholarly databases that will reflect gaps across disciplines.

Declaration of competing interest

No known competing interests.

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