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The influence of artificial intelligence in higher education based on four thematic axes: a bibliometric study

A influência da inteligência artificial no ensino superior com base em quatro eixos temáticos: um estudo bibliométrico

La influencia de la inteligencia artificial en la enseñanza superior a partir de cuatro ejes temáticos: un estudio bibliométrico

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Main topic:
Artificial Intelligence (AI) in higher education
Main practical implications:
This article presents a bibliometric approach with important findings to stimulate future research in artificial intelligence applied to higher education. The main practical implication is to serve as support to build research agendas, especially in emerging countries.
Originality/value:
The article is original because it is not limited only to bibliometric analysis, but also seeks to problematize and understand the main trends. With all the AI boom, original perspectives are always necessary, especially from emerging and developing countries, where more progress in research and scientific literature of AI is needed.

ABSTRACT

The article presents a structured bibliometric study examining the impact of artificial intelligence (AI) in higher education across four thematic axes: AI in higher education, AI in education review, AI in the teaching-learning process, and AI tools applied to higher education. Research productivity and impact indicators are analyzed using data from major databases like Scopus, Web of Science, and ScienceDirect. Results reveal a significant increase in AI-related research output, particularly in machine learning, data mining, and learning analytics. The study highlights China and the United States as leading contributors to AI research in higher education. The findings highlight AI's evolving role in transforming higher education and the need for multidisciplinary research approaches to address emerging challenges and opportunities. However, limitations include the reliance on quantitative measures, the narrow temporal scope, and the limited focus on high-production countries. Future research should incorporate qualitative methods to explore practical applications and social impacts more comprehensively, consider a broader range of geographic contexts, and discuss ethical considerations around integrating AI into higher education.

Keywords: Artificial Intelligence (AI), Higher Education, Bibliometric Analysis, Research Trends.

RESUMO

O artigo apresenta um estudo bibliométrico estruturado que examina o impacto da inteligência artificial (IA) no ensino superior em quatro eixos temáticos: IA no ensino superior, IA na revisão da educação, IA no processo de ensino-aprendizagem e ferramentas de IA aplicadas ao ensino superior. Os indicadores de produtividade e impacto da pesquisa são analisados usando dados dos principais bancos de dados, como Scopus, Web of Science e ScienceDirect. Os resultados revelam um aumento significativo na produção de pesquisas relacionadas à IA, principalmente em aprendizado de máquina, mineração de dados e análise de aprendizado. O estudo destaca a China e os Estados Unidos como os principais contribuintes para a pesquisa de IA no ensino superior. As descobertas destacam o papel em evolução da IA na transformação do ensino superior e a necessidade de abordagens de pesquisa multidisciplinares para enfrentar os desafios e as oportunidades emergentes. Entretanto, as limitações incluem a dependência de medidas quantitativas, o escopo temporal restrito e o foco limitado em países com alta produção. Pesquisas futuras devem incorporar métodos qualitativos para explorar aplicações práticas e impactos sociais de forma mais abrangente, considerar uma gama mais ampla de contextos geográficos e discutir considerações éticas sobre a integração da IA no ensino superior.

Palavras-chave: Inteligência Artificial (IA), Ensino Superior, Análise Bibliométrica, Tendências de Pesquisa

RESUMEN

El artículo presenta un estudio bibliométrico estructurado que examina el impacto de la inteligencia artificial (IA) en la enseñanza superior a través de cuatro ejes temáticos: IA en la educación superior, IA en la revisión de la educación, IA en el proceso de enseñanza-aprendizaje y herramientas de IA aplicadas a la educación superior. Los indicadores de productividad e impacto de la investigación se analizan utilizando datos de las principales bases de datos, como Scopus, Web of Science y ScienceDirect. Los resultados revelan un aumento significativo de la producción investigadora relacionada con la IA, sobre todo en aprendizaje automático, minería de datos y analítica del aprendizaje. El estudio destaca a China y Estados Unidos como principales contribuyentes a la investigación sobre IA en la enseñanza superior. Los resultados ponen de relieve el papel evolutivo de la IA en la transformación de la enseñanza superior y la necesidad de enfoques de investigación multidisciplinares para abordar los nuevos retos y oportunidades. Sin embargo, las limitaciones incluyen la dependencia de medidas cuantitativas, el estrecho alcance temporal y el enfoque limitado en países de alta producción. Las investigaciones futuras deberían incorporar métodos cualitativos para explorar más exhaustivamente las aplicaciones prácticas y las repercusiones sociales, considerar una gama más amplia de contextos geográficos y debatir las consideraciones éticas en torno a la integración de la IA en la enseñanza superior.

Palabras clave: Inteligencia artificial (IA), educación superior, análisis bibliométrico, tendencias de la investigación.

INTRODUCTION

The advance in technology has caused a change of habits in many of the world's population. With new technologies, people have changed how they connect, interact, read, write, and get information (Ahuja et., al 2023; Baidoo-Anu & Owusu Ansah, 2023). In this scenario, the need arises for Education to adapt to current times and social customs.

One of the main benefits of AI in Higher Education is the personalization of learning. AI systems can adapt to the individual needs of each student, providing them with a more centralized approach. Therefore, it can improve the retention rate and academic performance, as students are more motivated and engaged in learning.

In addition, AI has been used to improve the efficiency of administrative processes, such as enrollment management and curriculum planning. AI systems can analyze large amounts of data and provide valuable information for decision-making, which can help administrators of educational institutions improve planning and resource management (Nemorin et al, 2022; Moreno Padilla, 2019).

AI requires large amounts of data to train models, and many educational institutions need more data to meet this goal. However, there are some challenges in the use of AI in Higher education; among the main ones: are the need for more access to high-quality data and the ethical use of personal information. Another major challenge is resistance to change by some teachers and students. AI may require a significant reorganization of how Education is delivered, and teachers may feel intimidated by the technology. Some students may be uncomfortable with the idea of being assessed by a machine rather than an educator.

Likewise, the justification and significance of the analysis conducted within this study were based on three research questions that guided the work, derived from the primary motivation of knowing the state of the scientific literature regarding the incidence of artificial intelligence in Higher Education; these questions are:

- Which countries have the highest scientific production on artificial intelligence in Higher Education? What has been the production situation over time?
- Is there a productive relationship between the number of keywords and the thematic axes to be reviewed?

METHODOLOGY

The present work is framed in the documentary research modality, which is delineated according to criteria of analysis of topics related to the incidence of Artificial Intelligence and Higher Education (Incio Flores et al., 2021; Segarra, 2023), so a review of the scientific literature provided in the databases: Web Of Science (WOS), Scopus (S) and Science Direct (SD) was carried out; and the following thematic axes were examined:

A. The Influence of AI in Higher Education

Artificial intelligence has influenced Higher Education in several ways. For example:

In Personalization of Learning: AI has enabled universities and colleges to personalize student learning by analyzing each student's performance and needs, offering personalized recommendations to improve their learning (Vazquez et al, 2022).Task Automation: Universities and colleges have been able to automate many administrative and academic tasks.

Educational Data Analytics identifies patterns and trends in student learning. The results of this analysis can help universities and colleges make informed decisions about improving students' academic performance and learning experience. Innovation in Education, teachers can use AI to develop new teaching and assessment methods creating more interactive and personalized learning experiences (Chen et al., 2022).

Accessibility improves higher Education for students with disabilities and other marginalized groups. AI systems help students with visual or hearing limitations to access educational materials and can offer more inclusive learning experiences for students from diverse cultural and linguistic backgrounds.

B. Review, Advances of Artificial Intelligence in Education in the last three years.

In the last three years, AI has had several essential advances: Deep Learning, also known as deep neural networks, is one of the most active areas today. New deep learning architectures and techniques have been developed, significantly improving accuracy in various tasks, such as speech and image recognition. Natural Language Processing (NLP), since virtually any human language can be processed by computers through AI computers. In this way, the most widely used languages have applications in the digital world.

NLP techniques have been used in applications such as chatbots, virtual assistants, language translation, and sentiment analysis in social networks. Computer Vision has improved significantly in recent years thanks to deep learning techniques (Atkay, 2022). Object Detection and Recognition, Semantic Segmentation, and Image Classification are some tasks where significant progress has been achieved. Automation and Robotics are increasingly being used in industries. Robots and autonomous systems are in manufacturing, logistics, and transportation.

As AI is used in more applications and becomes more autonomous, its use also needs to be scrutinized through ethics and responsibility. New ethical frameworks and regulations have been developed to ensure that artificial intelligence is used without malice or deepening inequalities and divisions.

C. Artificial Intelligence in the Teaching-Learning Process

AI is a constantly evolving technology transforming how we interact with the world. One of the areas where a breakthrough is taking place is in the teaching-learning process. In this process, AI greatly influences the personalization of the student's educational experience; each learns according to their own pace and needs. This issue is achieved through data analysis and the creation of algorithms that allow teachers to design more effective educational programs (Atkay, 2022; Guzmán et al., 2023).

One of the significant benefits of AI in the teaching-learning process is the ability to adapt to the individual needs of each student (Guerrero-Quiñonez et al., 2023; Flores Masias et al., 2023). AI systems can monitor their academic performance and provide real-time feedback to help them improve their learning (Castaneda, 2023). In addition, these systems can identify areas where they need more support and grant personalized resources to meet those needs. Moreover, they can automate administrative tasks such as curriculum planning, student assessment, and teacher communication management. This system allows educators to focus on the most important educational activities, such as interacting with students and teaching critical skills.

Despite the benefits of AI in the teaching-learning process, there are also significant challenges to consider. One of the biggest challenges is the digital divide, as not all students can access the technology needed to benefit from AI in the classroom. Lack of access to technology may also contribute to greater inequality in Education, as more privileged students would have an advantage in accessing high-tech educational resources. Resistance to change on the part of some teachers and students will be another challenge to overcome. AI may require a significant reorganization of how Education is delivered, and some teachers may be intimidated by the technology. Some students may be uncomfortable with the idea of being assessed by a machine rather than a human (Flores-Vivar & Garcia-Peñalvo, 2023).

D. Artificial Intelligence Tools Applied to Higher Education

Some of the most common tools and programs that use artificial intelligence in Higher Education are Learning Management Systems, which are online platforms that students and faculty use to share and access educational content (Peñaherrera Acurio et al., 2022; Sapci & Sapci, 2020; Joison et al., 2021). Intelligent Tutoring Systems are used to provide personalized feedback and guidance to students. These systems can identify areas where students struggle and provide additional learning materials to overcome them.

Educational Data Analysis Tools allow us to identify patterns and trends in student learning. Adaptive Learning Platforms use artificial intelligence to adapt learning to the individual needs of each student (Ocaña-Fernández et al., 2019). These platforms can offer personalized materials and adjust the learning pace to meet each student's needs. Finally, Virtual Assistants are programs to answer questions and help students (Jara & Ochoa, 2020). These assistants can be beneficial for students who need help outside of teachers' office hours or for those with questions that cannot be answered online.

Algorithms Used by Artificial Intelligence

Artificial intelligence uses a variety of algorithms to process and analyze data:

Neural Networks are algorithms that simulate the functioning of the human brain (Chen, 2019). They consist of interconnected nodes that process information and send signals through weighted connections. Neural networks use in machine learning tasks such as image recognition, natural language processing, and prediction.

Decision trees are a supervised learning technique used to classify and predict data. The algorithm builds a decision tree based on the features of the training data and uses this tree to classify new data.

Clustering is an unsupervised learning technique used to group similar data. The clustering algorithm looks for patterns in the data and groups data points that are similar.

Regression is a supervised learning technique for predicting a continuous variable. The regression algorithm analyzes the relationship between input and output variables and uses this relationship to make predictions.

Random Forests is a supervised learning algorithm that uses multiple decision trees to make a prediction. Each decision tree is trained with a subset of the training data and combined to generate a more accurate prediction.

Reinforcement Algorithms are learning techniques in which the algorithm learns through feedback from its environment (Giró-Gràcia & Sancho Gil, 2022). The algorithm makes decisions and receives a reward or punishment for each action it performs, allowing it to learn more effectively how to make decisions in similar situations in the future.

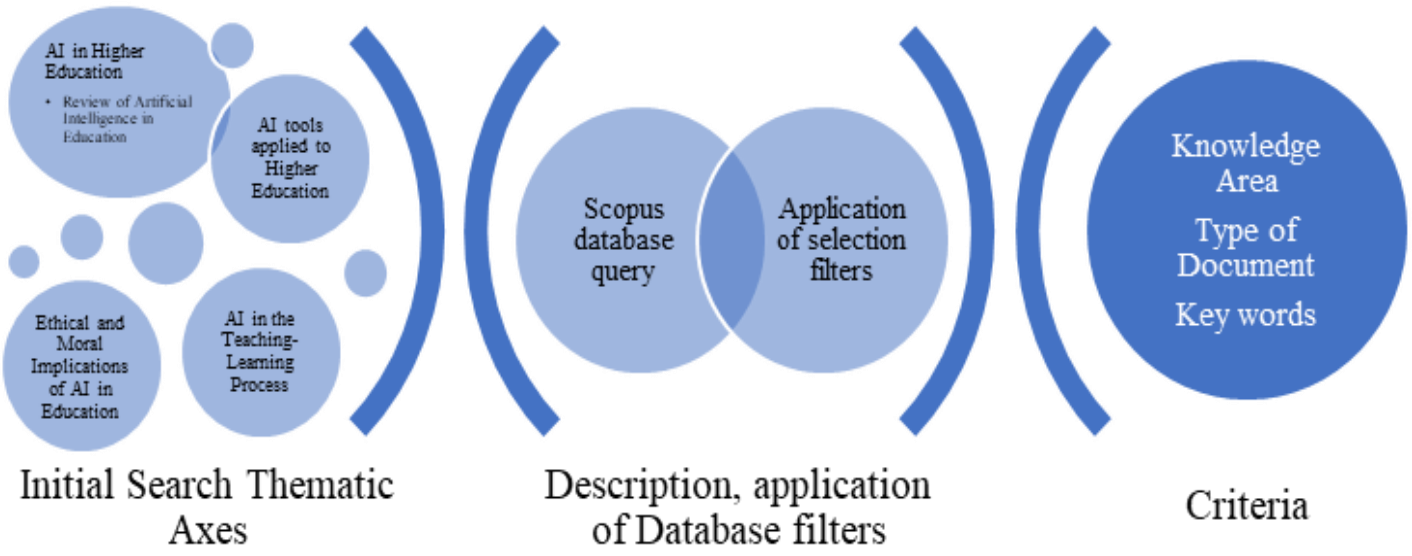
Influence of GPT Chat in Higher Education

ChatGPT has influenced Higher Education as a large-scale language model by enabling students and educators to access information and resources more quickly and efficiently (García-Peñalvo, 2023). Using natural language processing techniques, ChatGPT can answer questions and provide helpful information on various topics and knowledge areas (Baidoo-Anu & Owusu Ansah, 2023). Thus, students can use this tool to search for information on a particular topic, obtain definitions of complex concepts, ask questions related to their subject of study, or even generate ideas for research projects. Educators can also use it as a tool to prepare and create didactic materials and respond to students' concerns (Carrasco, 2024).

The above bibliographic analysis and review were carried out the second week of March 2024 following the parameters established by the PRISMA Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement (Urrútia & Bonfill, 2010) for which attention focused on the metadata of the scientific production of the last three years (2021 to 2023), taken from the database of most significant impact in the social sciences such as Scopus (SCImago Journal & Country Rank impact index-SJR).

A search for the thematic axes mentioned above was established. The results were limited based on thematic areas such as Computer Science, Engineering, and Social Sciences. In addition, the type of document selected was Articles and Reviews, considering keywords such as Artificial Intelligence, Students, Higher Education, and Engineering Education, considering the taxonomy associated with the Scopus database oriented to the science of Education.

Figure 1. Research framework proposed



Note. Own elaboration with the research data (2024).

Sample

The analysis was based on articles from journals indexed in Web of Science, Scopus, and Science Direct for each thematic axis, taking initial values given in Figure 1, then a sample was obtained for analysis purposes through the application of temporal filters for the years 2021 to 2023, and based on criteria such as area of knowledge, type of document and keywords, obtaining final values for the thematic areas reviewed.

Table 1. Thematic Axis results

THEMATIC AXIS	Web Of Science		Scopus		ScienceDirect	
	no	nf	no	nf	no	nf
Artificial Intelligence in Higher Education	10100	163	2287	304	2626	68
Artificial Intelligence in Education Review	3222	66	1797	264	33337	58
Artificial Intelligence in the Teaching-Learning Process	94	19	202	14	15648	34
Artificial Intelligence Tools Applied to Higher Education	347	15	58	12	16405	35

Note. Own elaboration with the research data (2024).

Data analysis

The variables of analysis were established according to the thematic axes using previous bibliometric studies (González & Silveira; Hinojo-Lucena et al., 2019; Parra-Sánchez, 2022). In addition, different bibliometric laws were applied: Price's Law and Lotka's Law, (Manthiramoorthi et al., 2019; Rousseau & Rousseau, 2000) establishing the indicators.

- Production indicator diachronic productivity.
- Impact indicator: Influence of countries and authors on the scientific production of each thematic axis.

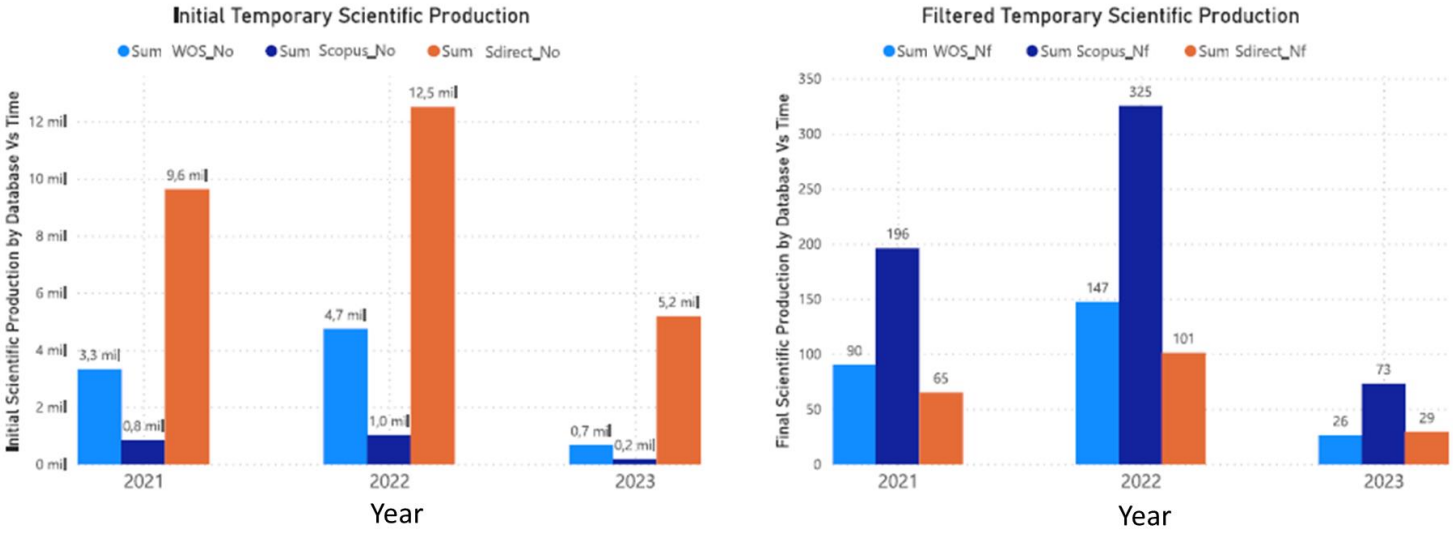
The data analysis was performed based on information obtained from WOS and Scopus. In addition, some analyses required Power BI software. For example, VOS viewer was used for correlations between authors and several articles.

RESULTS

Production Indicators

The production per year for the last three years is considered. The graph makes it possible to visualize the production in the different bibliographic databases. It is recorded that there has been more production about Artificial Intelligence in ScienceDirect in all the years. However, the production in the year 2022 is denoted. However, after performing a filtering of the cited articles taking into account the following subject areas such as Engineering, Computer Science, Social Sciences, type of documents to be reviewed, Articles and Reviews were selected and filtered in terms of Keywords: Artificial Intelligence, Higher Education, Engineering Education, Education, and Students, we have a production of 196, 325 and 73 articles in Scopus for the years 2021, 2022 and 2023 respectively.

Figure 2. Production indicators



Note. Own elaboration with the research data (2024).

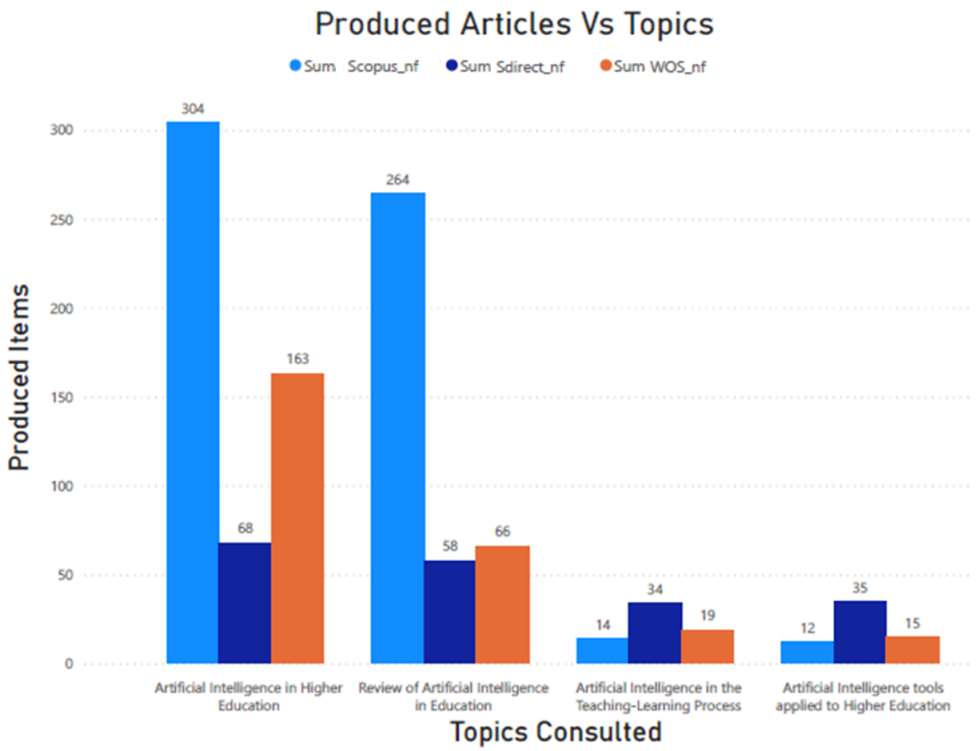
Lotka's law is applied in bibliometrics, which deals with the quantitative analysis of scientific production. This law is used to measure authors' scientific productivity and establish comparisons between scientific disciplines and their respective subjects. The productivity graphs shown determine the number of authors who have published a given number of articles in the discipline of Artificial Intelligence. It should be noted that Lotka's law is empirical.

Impact Indicators

As can be seen in the Figure 3, the impact of the production of articles related to all the topics have been published 56% in Scopus (S), 25% in Web Of Science (WOS), and 19% in Science Direct (SD). As for the First Thematic Axis, "Artificial intelligence in higher education," 57% have been published in S, 30% in WOS, and 13% in SD. In the Second Thematic Axis, "Review of Artificial Intelligence in Education," 68% in S, 17% in WOS, and 15% in SD. The contribution for the Third Thematic Axis, "Artificial Intelligence in the Teaching-Learning Process," was 21% in S, 28% in WOS, and 51% in SD. And finally, in the Fourth Thematic Axis, "Artificial Intelligence Tools Applied to Higher Education," 19% in S, 24% in WOS, and 56% in SD.

Therefore, the most significant number of publications are in Scopus. There is a thematic review of Artificial Intelligence in Education, with fewer articles produced related to AI in the teaching-learning process; although in recent months, there have indeed been several AI applications as tools to help Education, however, they are not recorded in scientific writing because as tools they use the same algorithms in different contexts. No formal scientific production exists, and researchers do not register their applications for intellectual property issues.

Figure 3. Impact indicators



Note. Own elaboration with the research data (2024).

As for the countries that produced the most literature, China and the United States occupied the first places in the first thematic axis in both databases, representing 40% and 11% (Scopus) of the total production. However, the impact ratio is still higher for the United States (Table 2).

Table 2. Impact indicators

Country	Documents	Citations	%Docs	Impact Cites/Doc
China	114	284	40%	2.5
Unidad States	32	154	11%	4.8
Spain	20	109	7%	5.5
United Kingdom	19	106	7%	5.6
Saudi Arabia	18	77	6%	4.3
Australia	12	71	4%	5.9
India	12	26	4%	2.2
Malaysia	9	11	3%	1.2
Mexico	9	27	3%	3.0
Russian Federation	9	33	3%	3.7
Taiwan	9	46	3%	5.1
Sweden	7	33	2%	4.7
Germany	6	16	2%	2.7
South Korea	6	16	2%	2.7
Brazil	5	2	2%	0.4

Note. Own elaboration with the research data (2024).

It is no secret that two countries that represent the largest global economies, the United States and China, are today disputing hegemony in various ways, and technology and artificial intelligence do not escape this dispute (Saveliev & Zhurenkov, 2021; Nguyen & Hekman, 2022). Both have robust strategies and large investments (Lee, 2018) but specifically at the level of research impact if analyzed by metrics, the United States still seems to be in the lead. On the other side, it is also interesting to note the outstanding performance of some emerging countries in terms of AI, and surprisingly, despite being once far from high research performance in high-tech issues, such as the case of Saudi Arabia, and its recent strategies of modernization and scientific and technological development (Meo et al., 2013; Hassan, 2020). These countries may be revealing new capabilities given the future of the use of AI in education.

Currently, AI is an active field of study around the world. Here are some countries, educational institutions, and companies conducting artificial intelligence studies: The United States is a leader in artificial intelligence research and development. Many US universities, such as Stanford, MIT, and Carnegie Mellon, have research programs in artificial intelligence. Several US technology companies, such as Google, Amazon, and Microsoft, are investing in artificial intelligence. Then there is China, which has invested heavily in artificial intelligence recently. Several Chinese universities, such as Tsinghua University and Peking University, have research programs in artificial intelligence. Chinese technology companies like Baidu, Alibaba, and Tencent also invest in artificial intelligence. The United Kingdom is home to several world-renowned universities, such as Oxford University and Cambridge University, with research programs in artificial intelligence. The European Union has launched an initiative to invest in artificial intelligence research and development. Several European universities, such as the University of Helsinki and the Technical University of Munich, have research programs in artificial intelligence. Several European technology companies are investing in artificial intelligence, such as Siemens.

In summary, so far we have been able to respond to the main answers of the study, where: 1) the largest global economies continue to dominate the trends in scientific research results in the thematic areas defined. However, the presence of emerging countries is a finding that deserves attention. 2) The general thematic areas yielded higher productivity results, as expected, which may indicate that the specific application of AI in the university educational context and teaching/study practice may still have future advances in scientific research.

CONCLUSIONS

In conclusion, the literature review on the impact of artificial intelligence (AI) in higher education reveals a dynamic and ever-changing environment. There have been significant scientific advances in the application of AI in higher education, particularly in areas such as machine learning, data mining, and academic assessment Trend analysis shows that AI is being used as an increasingly powerful tool for students and faculty in higher education.

The availability of advanced language programs such as ChatGPT has facilitated faster and more efficient access to information and resources, enabling students to search for information, understand complex concepts, and generate ideas for research projects Teachers can use AI. Regarding the geographical distribution of scientific output, China, the United States, Spain, and the United Kingdom are notable, showing global interest and investment in AI research for higher education but, it is necessary to observe the increasing research performance of emerging countries such as Saudi Arabia.

The higher prevalence of results in the general thematic axes can be attributed to several factors. Firstly, these axes, like bibliometric analysis and impact indicators, cover a broader spectrum of research within artificial intelligence in the higher education domain. They provide comprehensive insights into research productivity and influence across the field.

Moreover, these general thematic axes often act as initial points for researchers to delve into more specific areas within the broader field. For example, scholars may initiate their exploration by conducting bibliometric analyses to identify prevailing trends and influential contributors before narrowing their focus to specialized topics such as AI's role in the teaching-learning process or its applications in higher education tools.

Furthermore, the general thematic axes typically embrace a wider array of research methodologies and study designs compared to their more specific counterparts. This inclusiveness likely contributes to a higher volume of publications falling under these broad categories. In summary, the prominence of general thematic axes underscores their foundational significance in shaping our comprehension of overarching trends and dynamics within artificial intelligence in the higher education realm. Despite the progress made, there are still areas for research and challenges to overcome. Higher education must continue to encourage international collaboration and investment in AI research and to address the ethical and equity issues surrounding its use.

Main limitations of the study and future research

The study faces a notable limitation in its heavy reliance on bibliometric analysis, which predominantly emphasizes quantitative measures of research output and impact. While bibliometrics analyzes the quantity and influence of research within artificial intelligence in higher education, the results may overshadow qualitative aspects such as the depth of analysis or the practical implications of findings. The article in turn may have neglected gray literature. Additionally, the study's narrow temporal scope, confined to the past three years, might overlook longer-term trends or developments in the field, potentially missing significant contributions from earlier research. Furthermore, the geographic focus primarily on countries with high research output might disregard perspectives and contributions from emerging economies or regions with a growing interest in artificial intelligence and higher education. To mitigate these limitations, future research could integrate qualitative methods to explore the practical applications and societal impact of artificial intelligence in higher education more deeply. Additionally, considering a broader range of geographic contexts and historical perspectives would enrich the study's insights. Finally, a more comprehensive discussion of ethical considerations approaching the integration of AI into higher education settings would be relevant for guiding future research and policy decisions responsibly and ethically.

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B. data research and statistical analysis:	25%	25%	25%	25%
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