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Bibliometric Analysis of the Evolution of Artificial Intelligence Research Applied to Education

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Abstract: Artificial Intelligence (AI) is a new technology that has the potential to revolutionize education by providing personalized learning experiences and enhancing many educational processes. This paper used a hermeneutic approach based on a mixed methodology to carry out a bibliometric analysis of the scientific publications indexed in the Scopus database, focusing on the keywords AI and Education, limiting the results to those publications categorized in the field of Social Sciences. The results reflect 3875 indexed Social Sciences documents proposing the integration of AI in Education. From the results obtained, it is possible to ratify the significant impact of artificial intelligence in the educational sector. The analysis facilitates implementing innovations in the classroom, whether working on skills and soft skills, developing educational theories, adapting AI systems to specific educational environments, and configuring social values.

Key Words: artificial intelligence; learning; educational innovation; social values; universities; educational theories.

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1. Introduction

Artificial Intelligence (AI) is transforming many aspects of modern life, including education, and it can potentially improve the educational experience for both students and teachers. As a technology, it is a branch of computer science that includes cross-cutting concepts related to logic and learning. It involves designing computer tools that simulate human intelligence processes, including learning, reasoning, and self-correction (Avila, Mayer, & Quesada, 2020).

In essence, AI involves the development of computer systems capable of performing tasks that would typically require human intelligence—for example, understanding natural language, recognizing images, or solving problems. Some of the crucial techniques in AI are machine learning, which involves training computer systems to recognize patterns in data and make predictions based on them. Another essential technique is natural language processing, which teaches computers to understand and generate human language.

Other fundamental concepts of AI are knowledge representation and reasoning, which represent information about the world so that a computer can understand and use it to draw conclusions and make decisions. Planning and decision-making are also needed, involving the development of algorithms that can help computers make informed decisions based on available information. Artificial intelligence (AI) has undergone tremendous development since its inception. As presented by Shao, Yuan, Wang, and Xu (2021), its evolution and trends can be analyzed from four dimensions: research, production, influence, and competition.

One of the research dimensions of most significant interest today is its application in education (Barrios, Díaz, & Guerra, 2019; Zawacki-Richter, Marín, Bond, & Gouverneur, 2019; Nalbant, 2021). It can revolutionize how students learn, and AI can automate many tasks previously performed by humans, such as analyzing large data sets and providing personalized feedback to students. It can also create virtual learning environments and provide personalized learning plans considering each student's style.

Despite the many benefits of AI in education, some challenges need to be solved (Luan et al., 2020; Hwang, Xie, Wah, & Gašević, 2021). One of the main ones would be to be able to adapt to changing environments and ensure that their decisions are accurate and reliable. How has the evolution of AI research in education been up to today? This could provide us with valuable information about what has been and is being done in the field of educational research and help us establish the best strategies for integrating this technology in the future.

2. Literature Review

While AIs can be a valuable tool for helping students learn, human interaction is still essential for effective learning. Teachers can provide more detailed and personalized feedback than AIs and can help students develop critical social and emotional skills.

In this context, they were initially used mainly to simplify administrative tasks, such as student records management and course scheduling. Today, however, AIs have a much more significant impact on education. Since their incorporation in the 1970s, with the so-called "intelligent tutoring," there has been a remarkable evolution. At the beginning of the century, they were implemented as course recommendation systems, educational materials and resources, analysis of academic performance data, and later the emergence of educational chatbots and gamification. AIs in education, as advocated by Rouhiainen (2018), can bring positive aspects, such as being used to favor the personalization of learning processes, being able to analyze student data, such as their strengths and weaknesses, to create personalized study plans that adapt to the individual needs they present, which would imply the possibility of adapting to different rhythms and offering specific support and guidance, which would increase their motivation and improve their academic performance.

Analyzing its impact on the different curricular elements, following Moreno (2019), it can be pointed out that its main contributions would be found in the curricular objectives that can help personalize learning and adapt to students' individual needs can improve the effectiveness of teaching. In this way, more specific and personalized objectives can be developed according to the needs of each student. Likewise, its proper use would allow teachers to measure their students' progress more efficiently and provide constant feedback, thus favoring a more effective achievement of objectives. Moreover, in the contents, this is another thrilling application element that could favor creating more interactive materials adapted to individual needs to increase motivation towards learning.

On the other hand, in terms of assessment, AIs can automatically analyze students' work and provide them with real-time feedback, thus eliminating the need for teachers to spend hours reviewing assignments and exams. They can also be used to assess student progress and recommend improvement areas. Among the difficulties that the incorporation of AIs in education may present, it is considered essential to highlight the lack of human interaction, which is necessary for adequate emotional, social, and cultural development, as well as the lack of reliability associated with the fact that although it handles large amounts of information, it is not always reliable and accurate, or that the answers may be biased.

Regarding the repercussions these educational innovations would have on teachers and students, we can point out the effect on their roles and the required competencies. Specifically, regarding the role of teachers (Caballero, 2020), the incorporation of AIs would change significantly from being the primary source of knowledge and the classroom leader to facilitator and guide in the learning process, becoming their main function, supervising and adjusting the use of AIs in the classroom, adopting a more active role in the personalization of learning based on the recommendations of the AIs. On the other hand, from the students' point of view, their incorporation would require them to go from being passive receivers of information to active participants responsible for their learning.

The integration of AI in education is necessary, as well as other current emerging technologies that are not only part of our world today but will be increasingly important in the future (Gómez Galán, 2019 and 2021). In the case of the university, for example, it must adapt to the new intelligent technological trends, especially in the use of artificial intelligence and teacher training in learning ecologies multiple utilities presented by machine learning, big data, Deep learning, AI-based systems to establish predictive models to prevent university dropout, or to encourage healthy study habits in the student body, the implementation of chatbots or AI-based virtual assistants to solve student tasks and doubts, improve personalized learning itineraries, improve evaluation processes in a ubiquitous digital environment (Vázquez-Cano, Mengual and López-Meneses, 2021) and facilitate predictive models for adaptive learning as additional support for personalized tutoring of university students. In short, to improve the curricular competence model of educational ecosystems.

In terms of competencies and skills (Veytia et al., 2019; Bonami et al., 2020; Santamaría et al., 2021), in order to implement AIs in the classroom, teachers need to acquire skills and competencies related to the use of tools and technologies related to these technologies in the classroom, as well as the analysis of data generated by them. Therefore, students would need to learn to use the tools and technologies used in the classroom, such as the online learning platform, and acquire greater autonomy, decision-making capacity, and increased critical thinking and problem-solving skills.

Many existing studies on the application of AI systems in education highlight the issues related to intelligent tutoring to define the most appropriate practices for designing and evaluating student learning (Boden, 1984). Later, in the 1990s, research on using artificial intelligence in the design of collaborative learning environments and the personalization of learning (Joiner, 1994), and the use of data mining techniques for learning data analysis were explored (Roth, 1998). With the entry of the new millennium, the focus was established on artificial intelligence as a resource for adapting learning to the emotional and cognitive characteristics of the

student (Baylor, 2002), as well as on its use in plagiarism detection and the evaluation of the quality of educational content (Reis, Paladini, Khator & Sommer, 2006). While since 2010, the personalization of learning through the use of intelligent tutoring systems is again emphasized in the evaluation of the effectiveness of these systems in student learning and the design of intelligent learning environments (Wang & Wang, 2010) or in the automatic detection of emotions in the classroom (Vahabzadeh et al., 2018).

However, further research in this area can identify best practices and strategies for using artificial intelligence in education, helping educators and educational program designers make more informed decisions about using the technology effectively.

3. Materials and Methods

The present study is based on a hermeneutic approach with a mixed methodology, carrying out a bibliometric analysis of the scientific publications indexed in the Scopus database based on the keywords: *Artificial Intelligence* and *Education*, limiting the results to those publications categorized in the field of Social Sciences.

The search was conducted in English to cover a more significant number of publications. The analysis tools in the database were used: subject, type of publication, subject area, country, author, and year.

Subsequently, the data were subjected to a concurrence study using VosViewer software, delimiting the concepts related to the keywords identified, and a content analysis of the publications in Spanish was carried out, analyzing the approach proposed.

4. Results

The results reflect 3875 indexed documents in Social Sciences, which propose the integration of Artificial Intelligence in Education. As precursors of the subject, Scandura, Durnin, & Wulfeck (1974) already anticipated the implications of using artificial intelligence in education, referring to problem-solving. It is a field that is progressively gaining importance, but it is really with the beginning of this century when it takes off (see figure 1), with exponential growth, since in the three years that we have been in the current decade, it has already exceeded 36.16%, so far this year that has just begun and in 2 months 127 papers have been published in indexed media.

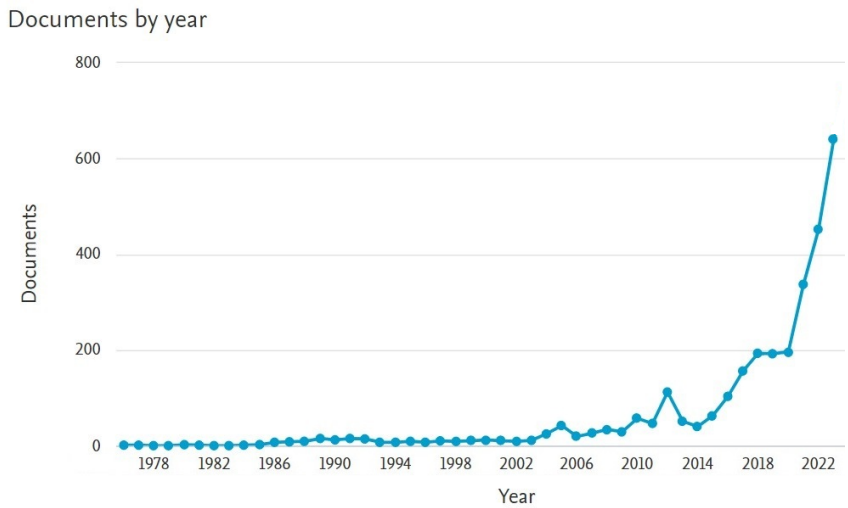

Figure 1. Historical evolution by year of publications in AI and education in Social Sciences. Source: Own elaboration based on Scopus database.

Although today the dissemination of research tends to be mainly through conferences and articles in similar percentages (Figure 2), this has evolved in phases. Although articles were the preferred medium until the year 2000, in the following two decades, papers acquired greater relevance, but in recent years journal articles have once again become the preferred medium (Table 1 and Figure 3).

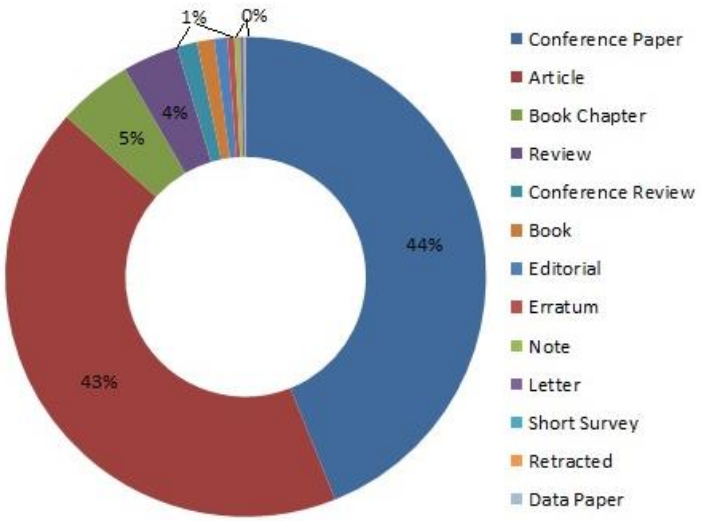

Figure 2. Type of documents of publications in AI and education in Social Sciences. Source: Own elaboration based on Scopus database.

	1974-1999	*2000-2009*	*2010-2019*	*2020-*
Conference Paper	37	171	848	646
Article	119	90	439	1007
Book Chapter		7	74	113
Review	3	18	30	94
Book		1	22	22
Conference Review	9	4	13	27
Editorial		6	8	20
Note			3	11
Erratum			2	16
Letter			2	7
Short Survey		1	1	
Retracted			1	1
Data Paper				1
Other	1			

Table 1. Type of document by stage. Source: Own elaboration based on Scopus database.

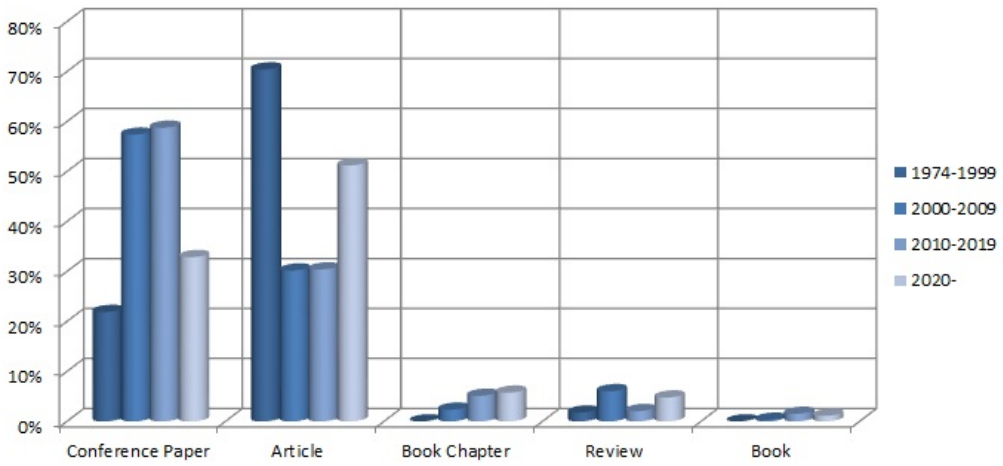

Figure 3. Type of documents of publications in AI and education in Social Sciences by stage. Source: Own elaboration based on Scopus database.

Concerning the origin of their production, eight countries stand out, with more than 100 publications: the USA (863), China (586), United Kingdom (293), Spain (198), Australia (155), Germany (142), India (138), Canada (127), Taiwan (110). In terms of language, 97% of the publications were in English (Figure 4).

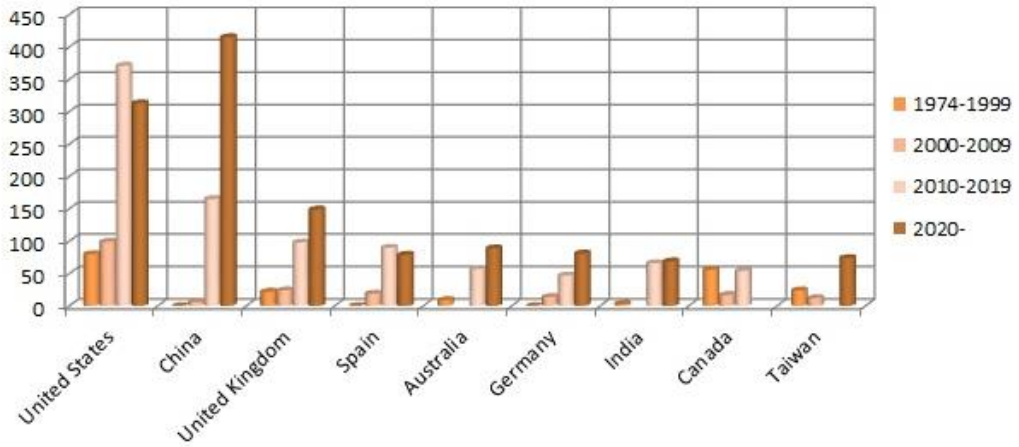

Figure 4. Publications by country in AI and education in Social Sciences by stage. Source: Own elaboration based on Scopus database.

From a qualitative analysis, the concurrency analysis (Figure 5) yields the following results, which we have grouped into five main categories: learning systems, artificial intelligence, intelligent tutoring system, education, and machine learning, which encompass 50 codes.

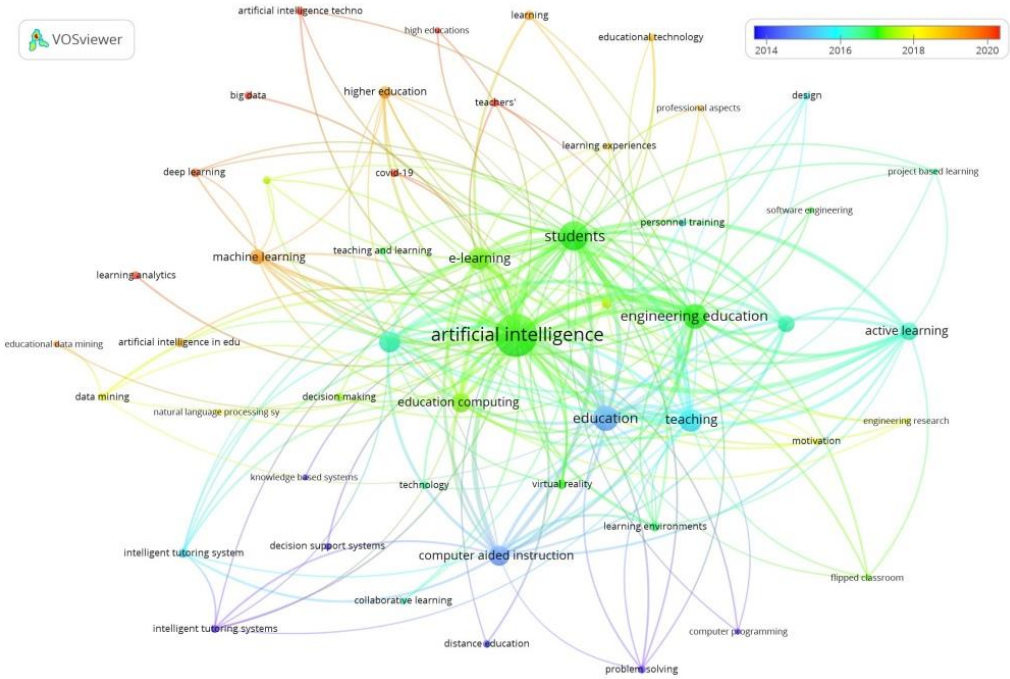

Figure 5. Concurrency cloud of the main categories and codes in AI and education publications in the Social Sciences. Source: VOSviewer.

5. Discussion and Conclusions

Our work is in line with other reviews of the evolution of AI in education by other authors, which show the growing interest in this crucial technology in this field. Among others, those by Chassignol, Khoroshavin, Klimova, & Bilyatdinova (2018) focused on trends in education, the classic introduction by Cumming (1998) almost two decades ago, announcing the potential of this technology, and the more recent reviews by Penstein et al. (2018), Chen, Chen, & Lin (2020) and Huang, Saleh, & Liu (2021) can be highlighted.

From the results obtained, it is possible to ratify the significant impact of AI in the educational sector. The progressive implementation analysis facilitates innovations in the classroom with its use, whether working on skills and soft skills, developing educational theories, adapting AI systems to specific educational environments, and configuring social values (Barrios et al., 2021). Likewise, scientific production on AI systems in education is increasing, as also corroborated by Chen et al. (2020), although especially since the beginning of the millennium and more specifically since the beginning of the last decade. Moreover, as Chassignol et al. (2018) indicated, AI has been incorporated into the administration, teaching, and learning processes.

AI in education today has novel applications, including student retention and dropout prediction, intelligent tutoring, classroom monitoring, and recommender systems (Ahmad et al., 2020). Intelligent tutoring systems can help students and teachers provide personalized support (Khazanchi and Khazanchi, 2021). AI-related educational assessment, meanwhile, is attracting increasing interest as a means to improve the effectiveness and validity of assessment (Gardner, O'Leary & Yuan, 2020).

Mills, Bosch, Krasich, & D'Mello (2019) determined that teaching and learning activities and practices would evolve with AI. Moreover, Goksel and Bozkurt (2019) considered it a forward-looking component of educational processes. However, as Cope, Kalantzis & Searsmith (2020) advocate, this novel technology will never be able to take over the role of a teacher altogether.

These aspects are relevant since, as Vázquez-Cano (2021) points out, we must adapt to the new reality and assimilate technologies as an element that can contribute multiple positive aspects to the formation of personal, educational, professional, and social competencies. To this end, it is essential to carry out bibliometric studies to show how we are working to improve the teaching-learning processes.

In conclusion, AI has the potential to revolutionize education by providing personalized learning experiences and enhancing many educational processes. However, it is essential to approach AI in education cautiously and

ensure it is depleted to enhance human interaction, not completely replace it. This underscores the importance of considering the human element in education and ensuring that AI is used to complement and enhance human interaction rather than replace it.

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