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Review Article

Bibliometric review on teaching methods with artificial intelligence in education

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ABSTRACT

The purpose of this article is to carry out an analysis of the disclosures made on teaching methods applying artificial intelligence in the Scopus database. The bibliometric review method was used to analyze 349 scientific articles dating from 1978 to 2023. The analysis was carried out using Bibliometrix and VOSviewer software, and the results show that from 2021 onwards there will be a notable increase in publications, with Mobile Information Systems being the journal with the highest production. Among 65 countries identified, China is the country with the highest production and the most productive organization was the Ministry of Education of the People's Republic of China. No single author stands out for his or her highest scientific output, given that the maximum number of articles published per author is two. However, among the most cited authors is Alimisis, D. and the most co-cited author is Wang, Y. In terms of co-authorship, there is little contribution between authors, while collaboration between countries, China together with Hong Kong, Japan, Malaysia, Mexico, South Korea, Taiwan, Thailand form the most collaborative conglomerate. Cooperation between institutions, the division of computer engineering and the National University of Singapore, show the strongest collaboration. The strongest keywords are "artificial intelligence", followed by "teaching methods" and "machine learning" and the topics that will be trending from 2021 onwards are "machine learning", "ChatGPT", "deep learning".

Keywords: teaching methods, artificial intelligence, bibliometrics, Scopus

INTRODUCTION

Any formal educational process requires a teacher to plan and carry out the task of teaching through various strategies that facilitate the learning experience. We call this task teaching methods, which consists of organizing a sequence of actions, activities or operations that the teacher carries out to direct a learning session and achieve educational objectives (Abdel & Bastami; 2012; Al-Ghasab, 2022; Nérici, 1985). The

teacher must draw on his or her didactic knowledge and experience to enable the success of the program and the learner to achieve the desired competences (Al-Ghasab, 2022). In this regard, it is important for teachers to choose appropriate methods according to the learning situation (Aktepe et al., 2015), due to the complexity of the education system. Their choice depends on many environmental factors (Rycroft-Malone et al., 2012) that must be considered, students' learning styles, available time, infrastructure, materials, level of studies, among other variables.

In an ever-changing world, there is a need to continuously improve teaching methodologies to achieve situated learning (Lave & Wenger, 2008). In the current digital era, education is undergoing accelerated changes by integrating technological advances into pedagogical processes. The use of new technologies is creating new challenges for traditional models of education, as well as for the entire education system (Chura-Quispe & Garcia Castro, 2024). Emerging technology in Web 3.0 and Web 4.0 provides a variety of digital tools that are available for use in educational activity. The integration of technological devices to support teaching methods is an almost inevitable necessity (El Hajj & Harb, 2023).

Artificial intelligence (AI) tools represent an innovative and promising model for addressing the changing needs of modern education (Ruiz-Rojas et al., 2023). AI can be defined as a subfield of computer science that is capable of solving various cognitive tasks associated with human intelligence: learning, problem solving, pattern identification and adaptation (Hwang, 2020). It is also defined as a theoretical basis capable of directing the creation and application of computer systems. This AI system can develop activities performed by human intellect, speech recognition, visual interpretation, translations into different languages (Nguyen et al., 2023), performance predictions (Shen et al., 2022), data mining (Nahar et al., (2021), assessment of learner engagement (Karsenti, 2019), and development of instructional designs (Ruiz-Rojas et al., 2023) among others. It plays an important role in educational process due to multiple applications that can be given to it.

In the field of education, AI has great benefits, but it also poses challenges over time. It can help teachers to stimulate students' interest by modulating teaching strategies (Cukurova et al., 2019). In this regard, there are bibliometric reviews reporting the progress and trends of AI applications in learning (Eguchi, 2020). Hamilton et al. (2018) conducted a systematic review on learning with the adoption of immersive virtual reality, identifying 21 articles published between 2013 and 2017, the results showed limited activity in the acquisition of cognitive, psychomotor and attitudinal skills of participants. In another study by Moreno-Guerrero et al. (2020), a scientific mapping was carried out in Web of Science on the projection of AI in education with different bibliometric indicators, 379 documents published between 1956 and 2020 were found. The paper highlights that the most important thematic area was educational research. In the same vein, Talan (2021) examined the literature on the use of AI in pedagogical activities in the Web of Science database. His report of 2686 publications between 2001-2021 shows that the most relevant topics are machine learning, deep learning and higher education.

Bibliometric review research on AI in education is gaining more interest among researchers. In this regard, Prahani et al. (2022) conducted a bibliometric analysis of the last 10 years (2011-2021) in the Scopus on trends in AI in education. Their VOSviewer mapping of 457 papers provided relevant information on trending topics: engineering education, e-learning, curriculum and student applications. The use of AI is making inroads at all levels of education. Chamorro-Atalaya et al. (2023) conducted a review in Scopus on application of chatbot in university students. He identified that in 210 manuscripts published between 2013 and 2023, there is a greater number of articles focused on improving university educational services than at other educational levels.

AI research is gaining importance due to the dynamics it can bring to the quality of education (Kong, 2020). With the use of this technology, teaching methods can be optimized by integrating the different tools it offers. In this context, several publications of bibliometric reviews have been published addressing the topic from a general view of education (Song & Wang, 2020). The works have been developed addressing the application of AI from different points of view, however, there are almost no exclusive scientific mapping studies on AI teaching methods. For this reason, there is a need to examine bibliometric properties to visualize the state of the art and assess research propensities. The present study aims to carry out a bibliometric analysis in the Scopus database on the dissemination of the topic of teaching methods using AI. In this sense, the aim is to visualize the total volume by years, authors, countries, institutions and journals; the trajectory of scientific production, keywords, co-authorship, co-citation, co-occurrence and trends in key topics.

Table 1. Scopus search query

Variable	Definition
Database	Scopus
Date	01.11.2023
Years	Todo
Categories	Todo (Scopus)
Language	Todo
Search equation	TITLE-ABS-KEY (“teaching methods” or “teaching strategies” or “teaching techniques” or “teaching methods” or “educational methods”) AND “artificial intelligence”
Result	995 documents
Refine search	
Type of document	Articles
Result	349 (articles)

METHODOLOGY

The method used for bibliometric mapping allowed us to identify and examine the connections among different publications on the topic of teaching methods with AI. This approach represents a type of quantitative research that involved the development of search strategies and the systematic extraction of data from documents retrieved from the Scopus database. Its main objective is to quantify and analyze bibliographic data to obtain information on patterns of academic communication, research productivity, the impact of scientific production, and trends in the subject under consideration.

Various techniques were employed, such as analysis of scientific production, trends (Briner & Denyer, 2012), co-authorships, and collaboration network mapping (Zupic & Cater, 2015). The procedures were based on the adaptations made by Govindan and Hasanagic (2018) and Mathiyazhagan et al. (2021). The study design encompasses two phases, with the first involving data retrieval and the second involving bibliometric analysis.

Firstly, the Scopus was selected as the database, as it is considered to be the source that records the largest number of journals. In addition, it uses consistent criteria for the induction of articles in its index. The target topic is called “teaching methods with artificial intelligence”, with this statement a search equation was elaborated that served as a filter to identify titles, abstracts and keywords (**Table 1**).

The data import was carried out in November 2023, the search period was not limited, and the language of publication was not limited. There were 995 documents meeting the search criteria and corresponding to the period 1976 to November 2023. The search was then refined to only scientific articles, yielding 349 documents.

At this stage, descriptive analyses were carried out with the help of the Bibliometrix web application based on R studio. This tool made it possible to identify the frequency of the total volume of production, by years, authors, countries, institutions and journals. This was followed by analyses of co-authorships (organizations, countries and authors), co-citations (authors and references cited) and co-occurrences (author keywords). These analyses were carried out with the VOSviewer 1.6.19 software, using the “full count” method in all cases, which gives a score of one as the author’s total weight (Perianes-Rodriguez et al., 2016). The results are presented through the visualization maps.

RESULTS

Figure 1 presents the results of the number of articles related to AI teaching methods. A total of 349 articles were collected dating from 1978 to November 2023. In 1978 the first research paper appeared, leaving a gap of four years, to be resumed in 1982, where another publication was recorded. After another four-year gap, two publications were published in 1986. In the period from 1986 to 2016, a maximum of 6 articles were published per year (between 2001 and 2003 and 2006 to 2007, no scientific production was recorded). It is from 2017 that the volume of production increases (15), in 2018 there were 11 documents, with a drop in 2019 (seven articles). In 2021, it rises to 46 and in 2022 the highest peak is recorded with 123, which represents 35.24% of the total number of articles, and until November 2023, 71 publications are recorded.

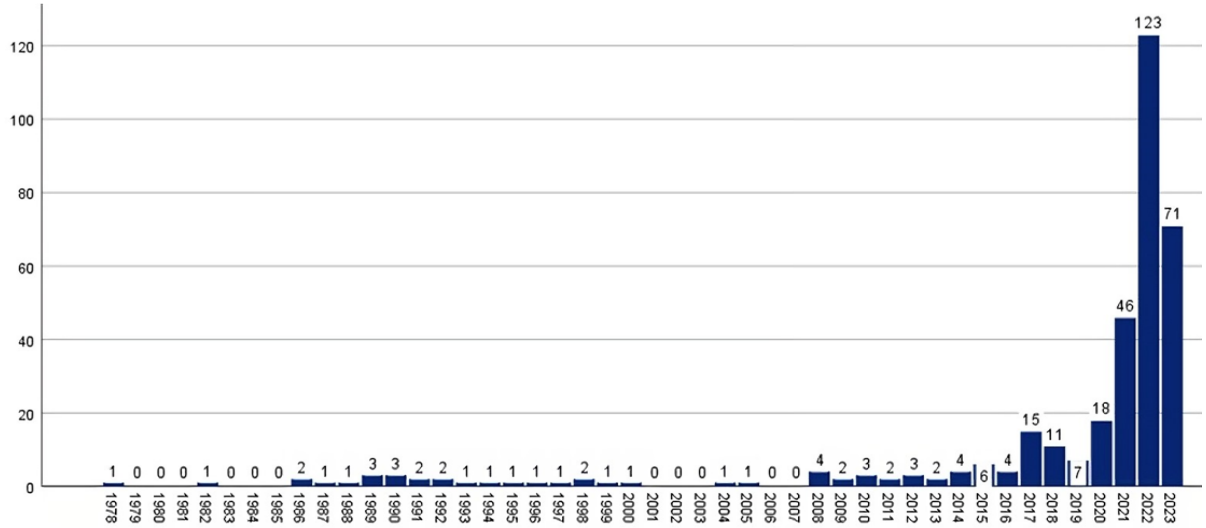

Figure 1. Number of publications per year on AI teaching methods (Source: Authors, using bibliometrix software)

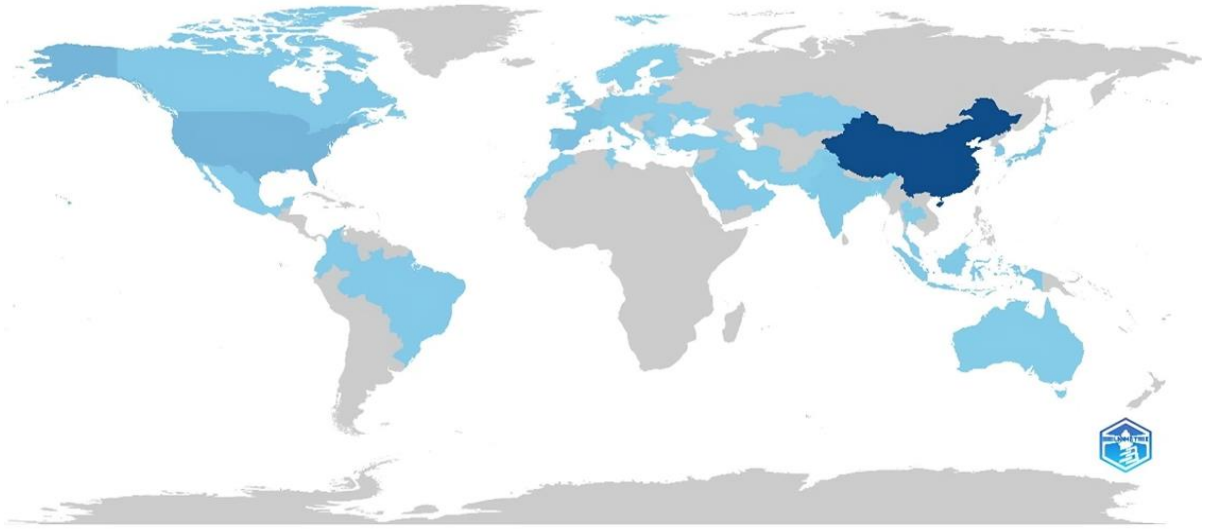

Figure 2. Number of articles by country between 1978 & 2023 (Source: Authors, using bibliometrix software)

Contributions by Country

The world map (**Figure 2**) shows the concentration of scientific production at the global level. The darker the blue color, the more articles published, and the grey color represents zero publications per country. It clearly shows that China leads the productivity with 197 manuscripts (56.70%) on AI teaching methods, followed by the USA with 33 articles, Spain 14, UK 12, Taiwan with 11, South Korea nine, and Indonesia five articles. The other countries have between one and four papers. We can also see that in South America, with the exception of Brazil and Colombia, the other countries on this continent have no publications. On the African continent the same thing happens, only Morocco has production, while in Northern Europe and Asia, Russia, and Greenland do not show any productivity.

Contributions from Organizations

Figure 3 contains only 11 of the 160 identified institutions that made contributions between 1978 and November 2023. The organization with the highest number of contributions is the Ministry of Education of the People's Republic of China (five articles), followed by Dongguan Polytechnic, Jiangxi Normal University, Dalian University, Shanghai University of Finance and Economics, Wuhan University of Science and Technology, University of Seville, Hebei Normal University, Central South University and Shanghai Jiao Tong University, all with three published articles.

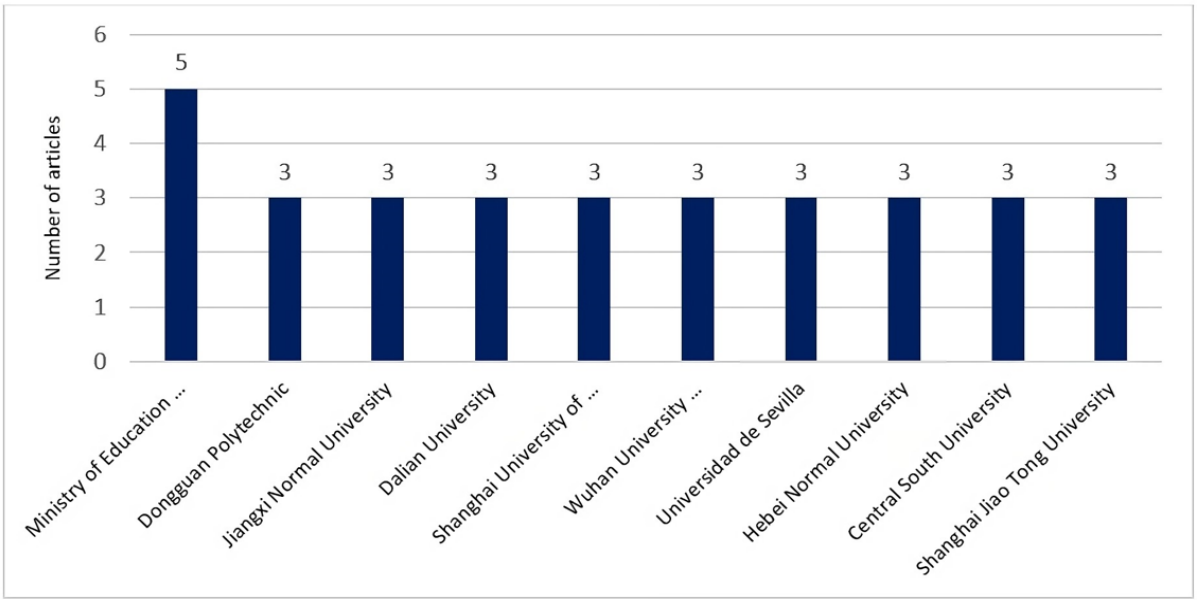

Figure 3. Number of articles by organization between 1978 & 2023 (Source: Authors)

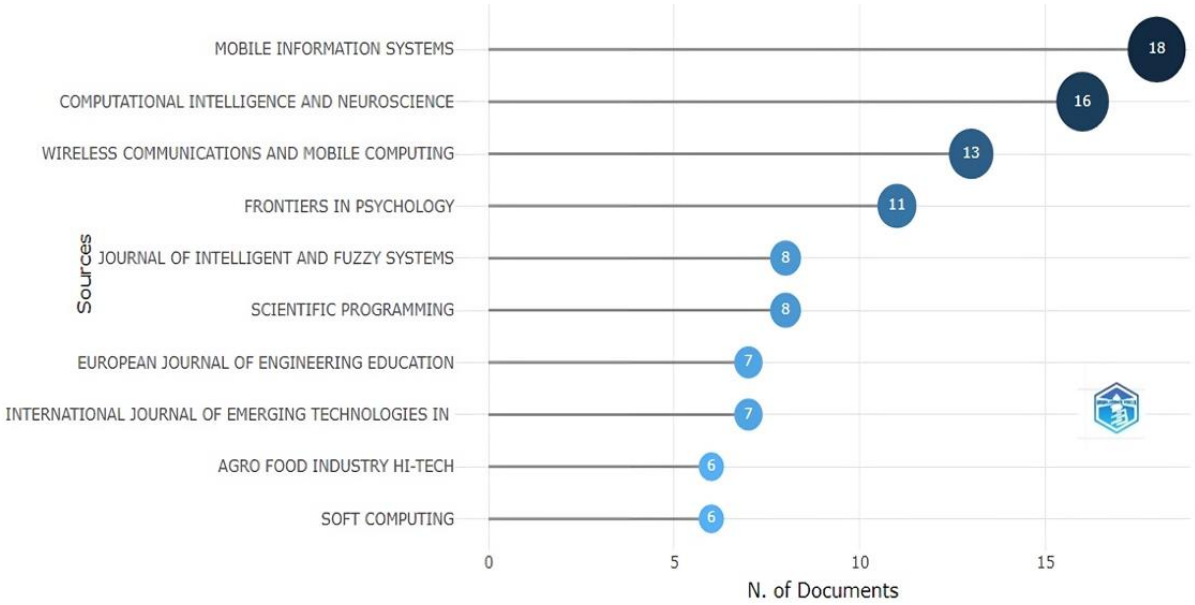

Figure 4. Number of articles per journal between 1978 & 2023 (Source: Authors, using bibliometrix software)

Contributions by Source

Figure 4 contains 26 of the 202 identified journals that published on AI teaching methods. Mobile Information Systems ranks first with 18 papers, followed by Computational Intelligence and Neuroscience with 16, then Wireless Communications and Mobile Computing with 13, Frontiers in Psychology with 11, the Journal of Intelligent and Fuzzy Systems and Scientific Programming with eight papers each. The journals that do not appear in the graph have less than two publications.

Contributions by Authors

Figure 5 shows the scientific output of authors on AI teaching methods worldwide. A total of 839 authors were identified who have published on the topic. Of which it can be seen that, as of November 2023, the top-13 authors have only published two papers each (Chum, H., Corno, F., De Russis, L., Hunyadi, D., Jiang, D., Kobayashi, N., Lai, Y. H., Li, G., Pah, I., Seya, K., Shirasaka, S., Tao, B., and Tu, Y. F.) and the remaining authors have only published one paper each.

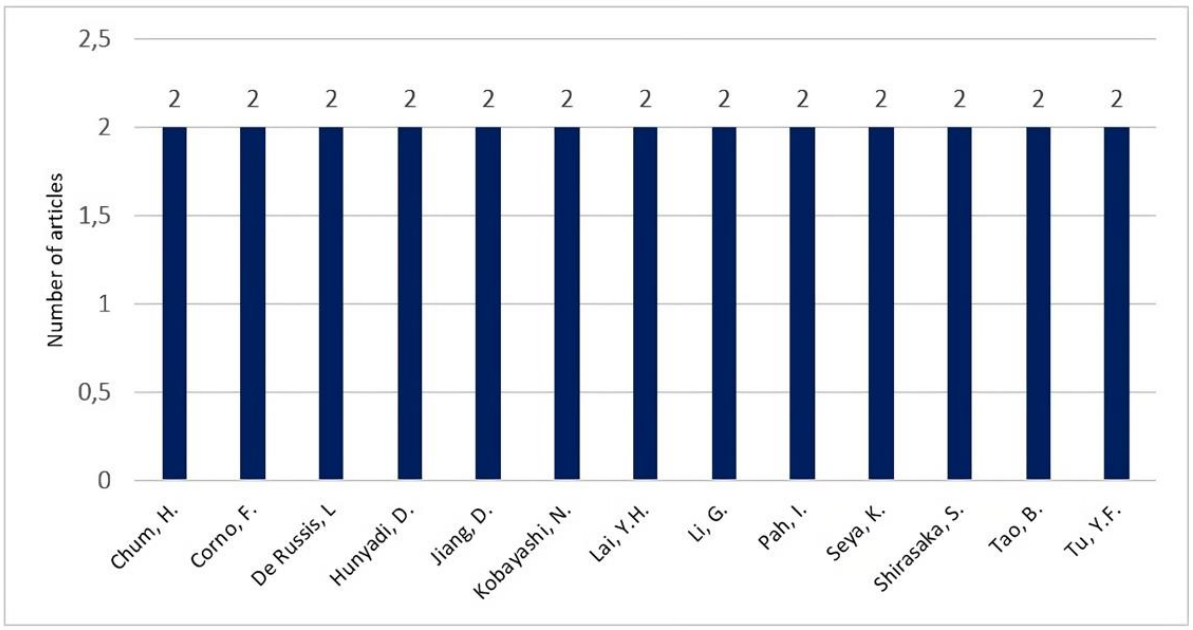

Figure 5. Number of articles per author between 1978 & 2023 (Source: Authors)

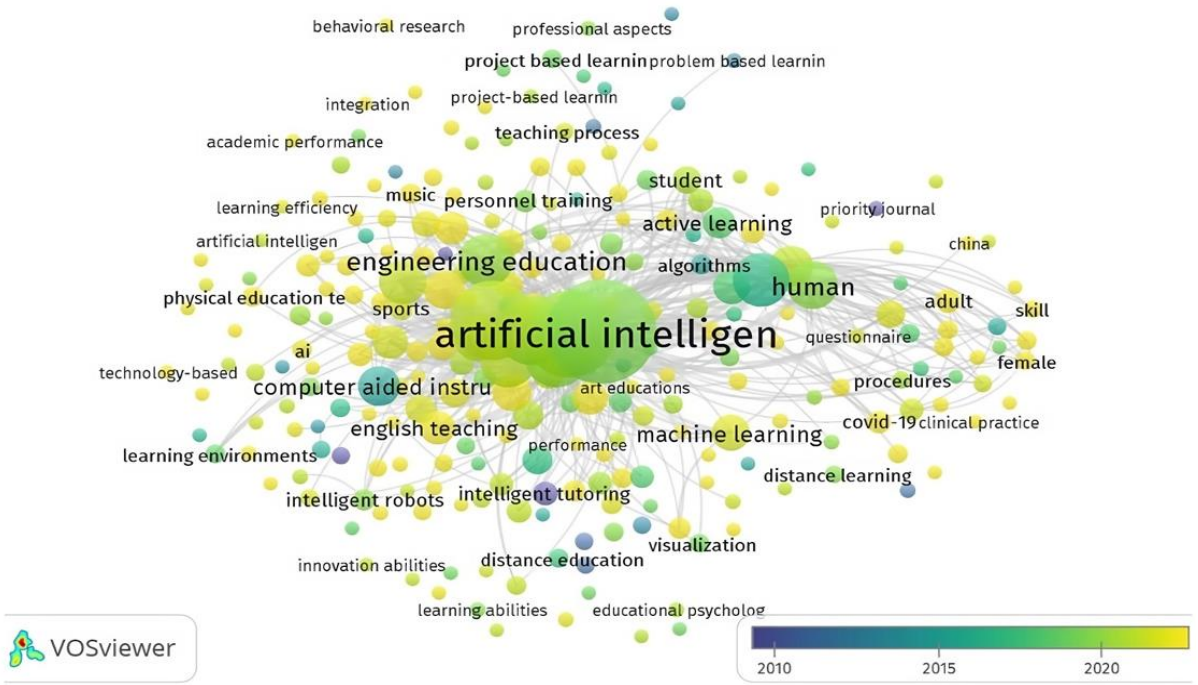

Figure 6. Scientific map of keyword co-occurrence between 1978 & 2023 (Source: Authors, using VOSviewer software)

Keywords

Figure 6 shows the scientific mapping of keywords based on co-occurrence. A minimum of three words was set as a criterion, 2,555 words were identified of which 258 reached the threshold. The terms showing the highest node magnitude is “artificial intelligence” (224 times), followed by “teaching” and “students” (152 and 126 times), another important word “teaching methods” (90 times); followed by “learning systems” (67 times), “e-learning” (51 times), “engineering education” (52 times), “education” (55 times), “education computing” (38 times). According to VOSviewer visualization overlay, in 2010 (blue) the themes of “intelligent tutoring”, “computer”, “computer aided instruction”, in 2015 (green) “education”, “computer aided instruction”, in 2020 (yellow) the theme of “artificial intelligence” appears very strongly and in 2023 the themes that emerge are: “machine learning”, “ChatGPT” and “deep learning”.

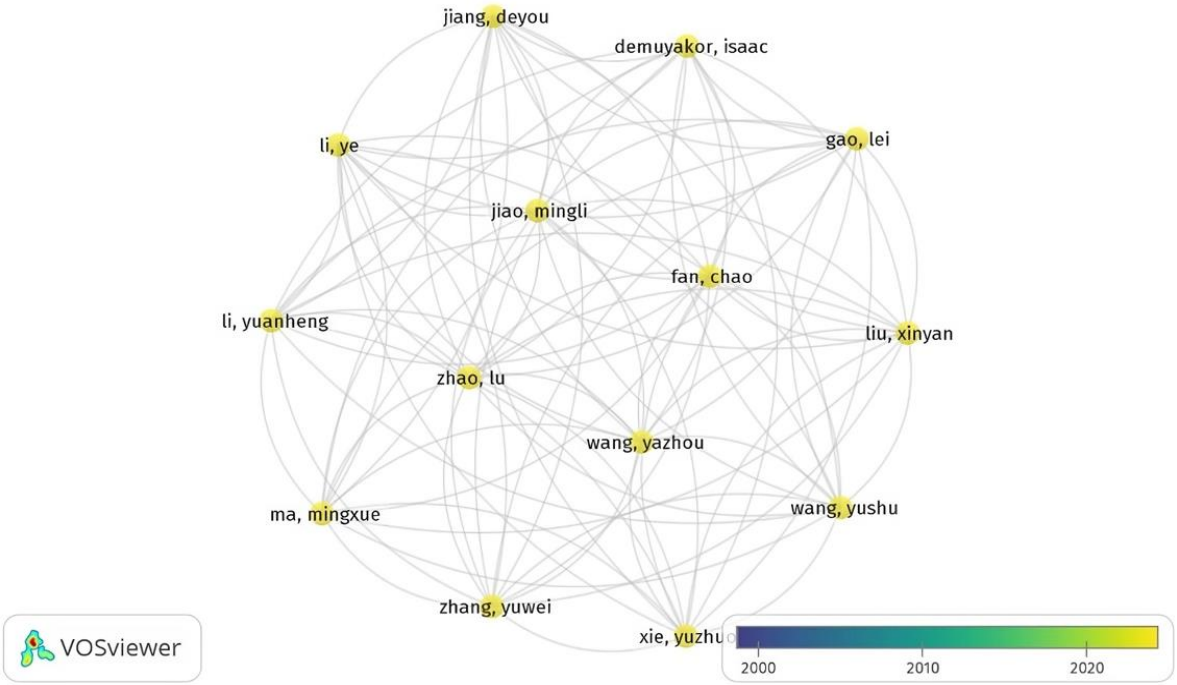

Figure 7. Scientific map of co-authorship network by authors between 1978 & 2023 (Source: Authors, using VOSviewer software)

Co-Authorship by Authors

The co-authorship visualization map for authors in VOSviewer (**Figure 7**) shows the strength of collaboration between authors on the topic of AI teaching methods. The mapping criteria was set to one article per author, in total 906 authors were registered. The single color (yellow) means that only one co-authorship group of 14 authors was formed, also indicating that it is from 2021 onwards that collaboration between authors takes place. The distances between the points indicate that there is a relative strength of collaboration, and the small size of the points indicates little production.

Co-Authorships by Country

Figure 8 contains the countries with the highest collaboration in publishing AI teaching methods. The network visualization map was developed by setting a minimum of two published articles per country or region (circles represent a country and their size represents the number of published articles). There were 65 countries worldwide, 36 of which meet the threshold, and five groups of relatively related countries were formed. Group 1 contains 10 elements (Czech Republic, Finland, France, Germany, Russian Federation, Serbia, Singapore, Switzerland, the United Kingdom, and the United states). Cluster 2 contains eight countries (China, Hong Kong, Japan, Malaysia, Mexico, South Korea, Taiwan, and Thailand) and has the highest strength of co-authorships. Group 3 contains six elements (Bulgaria, India, Indonesia, Oman, Saudi Arabia, and Sweden). Cluster 4 contains five elements (Brazil, Ecuador, Ireland, Portugal, and Spain). Group 5 contains two elements (Canada and Norway).

Co-Authorship of Organizations

Figure 9 shows the strength of collaboration between organizations, the minimum number was set at one, as there is little production. Under this criterion 678 organizations were identified, but the visualization map shows two groups: group 1 contains organizations such as National University of Science, Innovation Center of the School, Esperanto Technologies, Florida Atlantic University and Faculty of Civil Engineering, among others). Cluster 2 contains the Division of Computer Engineering and the National University of Singapore. In cluster 1, it can be observed that there is greater strength of collaboration between the institutions that make up the cluster, compared to cluster 2. In cluster 2, the two institutions that make up the cluster are far apart (Division of Computer Engineer 2010 and National University 2015). While the publications of cluster 1 are from 2020).

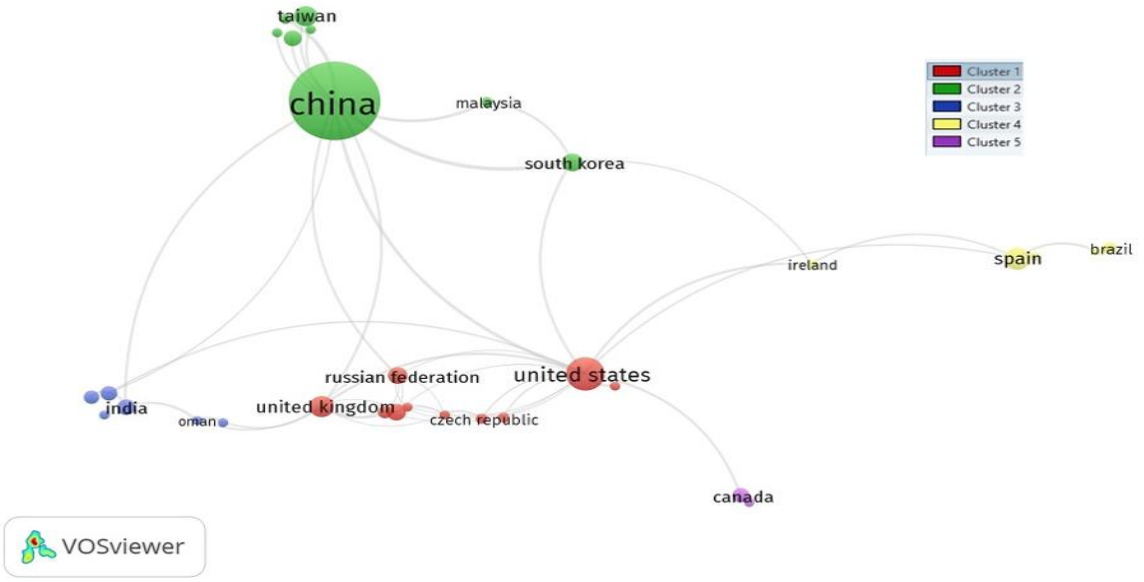

Figure 8. Scientific map of co-authorship network by country between 1978 & 2023 (Source: Authors, using VOSviewer software)

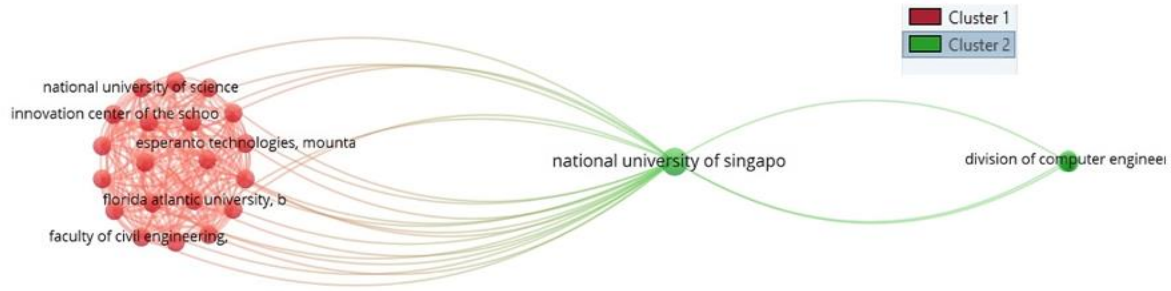

Figure 9. Scientific map of organizations' co-authorship network between 1978 & 202 (Source: Authors, using VOSviewer software)

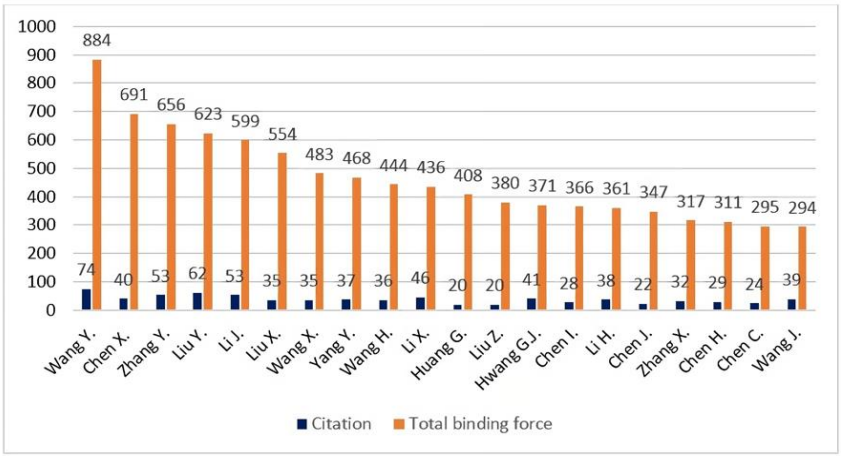

Figure 10. Co-citation of authors cited between 1978 & 2023 (Source: Authors, using bibliometrix software)

Co-Citations of Cited Authors

Figure 10 shows the results of co-citations of cited authors, which refers to the incidence with which two articles are simultaneously referenced by other articles, while there is bibliographic coupling (van Eck & Waltman, 2023). The elaboration criteria in VOSviewer was set to at least 20 citations of the 19348 authors 39 reached the threshold, in **Figure 10** we only present the top-20 authors. According to the total link strength Wang, Y. is the most co-cited author in the Scopus database, followed by Chen, X. and Zhang, Y.

Table 2. Co-cited references

No	Author(s)	Title	Year	C	F
1	Alimisis	Robotics in education & education in robotics	2012	5	35
2	Pina	Improving learning and motivation of students by using educational robotics in different scholar scenarios	2015	4	32
3	Perula-Martinez, Garcia-Haro, Balaguer, and Miguel	Developing educational printable robots to motivate university students using open source technologies	2016	3	27
4	Cai, Fang, Wen, Mumtaz, Song, and Frascolla	Multi-carrier M-ary DCSK system with code index modulation: An efficient solution for chaotic communications	2019	3	15
5	Chandra, Marcano, Mumtaz, Prasad, and Christiansen	Unveiling capacity gains in ultra-dense networks: Using mm-wave NOMA	2018	3	15
6	Saghezchi, Radwan, Rodriguez, and Dagiuklas	Coalition formation game toward green mobile terminals in heterogeneous wireless networks	2013	3	15
7	Wu, Lei, He, Zhang, and Ji	Deep reinforcement learning-based path control and optimization for unmanned ships	2022	3	15
8	Song and Wang	A bibliometric analysis of worldwide educational artificial intelligence research development in recent twenty years	2020	3	5
9	Wu, Wang, Zheng, and Wu	Effect of narcissism, psychopathy, and machiavellianism on entrepreneurial intention–The mediating of entrepreneurial self-efficacy	2019	3	5
10	Wu and Song	Gratifications for social media use in entrepreneurship courses: Learners' perspective	2019	3	5

Note. C: Citation & F: Total binding force

Co-Citation of Cited References

Regarding co-citation of cited references (**Table 2**), it was constructed from the information provided by VOSviewer in which three references were set as a minimum of one cited reference. Out of 10,840 references 24 reached threshold, **Table 2** contains only 10 of the 24 references. The highest cited reference co-citation is from Alimisis, D. who published his work in 2012, he has five citations and 35 strong links in total, followed by Pina, A. who published his work in 2015 and currently has four citations and 32 links of total strength.

DISCUSSION

The research addresses the need to share knowledge about the incursion of "artificial intelligence" in teaching processes. A technology with fundamental capabilities that is advancing at great speed and is integrated into all kinds of uses of educational systems.

Its application in the development of teaching methods has been the objective of this work. Through a bibliometric review, it was determined that the first publications on the subject appeared in 1978. History reports that its production has had periods with very low production (two to six publications). The same was reported by Moreno-Guerrero et al. (2020), who concluded that AI studies registered in Web of Science in the field of education have been irregular since its beginnings (1956). Since 2020 it has been increasing substantially and in 2022 it reached the highest productivity. Prahani et al. (2022) also concluded that in the last three years the publication rate increased by a margin of 85.56% of the total number of articles reviewed between 2011 and 2021.

The articles published by author show that to date there is no visible author who stands out for his or her major output. Of the 839 authors identified, only 13 have at most two published articles and the rest only one. In contrast, in similar work we see the leadership of authors interested in AI education, Talan (2021) found that Kurt, V. and Chih-Ming, C. both with 10 articles are the leading authors in terms of publications between 2001 and 2021. The co-authorship visualization map was organized into a single collaboration group (consisting of 11 authors), whose linking strength is very weak and only appears from 2022 onwards. This situation is also manifested in other works, Esti et al. (2023) in their analysis of co-authorships found only 6 collaborative researchers that make up 3 groups with low linking strength.

In the co-citation analysis of cited references, Alimisis, D. was identified as having the highest total link strength, with the article published in 2012, entitled "robotics in education & education in robotics", followed by Pina, A. in 2015, who published the article "improving learning and motivation of students by using

educational robotics in different scholar scenarios". These findings provide specific information on experiences that analyze the impact of AI tools in educational processes.

The findings on the number of articles per source indicate that the journal with the highest output is "Mobile information Systems", followed by "Computational Intelligence and Neuroscience". In Kaban's (2023) bibliometric review work, the journal with the highest output was "Education and Information Technologies". Talan (2021) found that the journal with the highest number of publications was "Computers & Education". As can be seen, the journals do not coincide with our findings, this is due to the diversity of approaches to AI in the educational field. Another thing we noticed is that most of the journals that are interested in disseminating research work on the subject are those specialized in the field of technologies applied to education.

Other findings are related to the production of institutions, in our case the Ministry of Education of the People's Republic of China, which belongs to the People's Republic of China, stands out as occupying first place. The report on co-authorships between organizations indicates that they will gain strength from 2020 onwards, including the National University of Science, Innovation Center of the School, Esperanto Technologies, Florida Atlantic University and Faculty of Civil Engineering, among others. In other works, collaboration between organizations was null, but the Department of Computer Science and Architecture of the Polytechnic University of Catalonia and the University of Karistad in Sweden were identified as outstanding organizations for their production.

In terms of article production by country, our analysis reveals that China leads the world in scientific article production, followed closely by the United States. The co-authorship information by country reports that China forms the strongest collaboration cluster with Taiwan, South Korea, and Malaysia. Prahani et al. (2022) also concluded that China is the most active country in the production of scientific articles, thus, it is the country with the highest interest in AI applications in education.

The analysis also showed that the most popular words are: "artificial intelligence", "teaching methods", and "machine learning". The visualization map shows that these words form the largest node, but their prevalence is from the year 2020 onwards. Pu et al. (2021) in the review work on the central themes in AI education research found similar keywords such as, e.g., "learning systems" and "computer-assisted teaching". These results indicate the variety of approaches that exist among researchers when dealing with AI in education. We can also identify that currently in 2023 emerging themes are "machine learning", "ChatGPT" and "deep learning". These findings are in line with the results of Kaban (2023) and Talan (2021), who identified "artificial intelligent" and "machine learning" as the most relevant keywords. Prahani et al. (2022) concludes that among the topics that are currently emerging are "teaching methods", "e-learning based education" and "education system", these results were obtained through a literature review of the last 10 years of AI research in education.

CONCLUSIONS & LIMITATIONS

As a result of the bibliometric review, we can observe that there are currently AI tools specifically designed to integrate into teaching methods across all educational levels, from basic to higher education. The earliest publications on this topic date back to 1978, and in the last two years, there has been a notable increase in the production of articles on AI teaching methods. Review indicators point out that the Egyptian journal "Mobile Information Systems" has the highest production, and among 65 countries, researchers from China lead in production. The organization leading the production is the "Ministry of Education of the People's Republic of China".

No single author is reported to have a major output (maximum two papers). Among the most cited authors is Alimisis, D. and the most co-cited author is Wang, Y. The most frequent keywords mentioned in the articles are "artificial intelligence", "teaching methods", and "machine learning". The most important emerging themes among the publications are "machine learning", "ChatGPT", and "deep learning". The co-authorship analysis indicates that there is little strength of collaboration between authors, as well as collaboration between countries and collaboration between institutions. It is also important to note that the article robotics in education & education in robotics is the most cited article.

The information contained in this article can serve the analysis of the state of the art for future research. In the present study only scientific articles (349) were addressed in the Scopus database, which can be accessed according to the search equation, so that several databases could be considered to extend the analysis. In addition, the inclusion of other types of documents can be considered. Also, not all articles were found to have a specific treatment on the design of AI teaching methods.

On the other hand, bibliometric analysis solely focuses on measuring the metadata of articles, without addressing the analysis of their contents. Future studies could delve into this area through other research designs. The lack of collaboration among authors, countries, and institutions highlights the need to promote collaboration and knowledge exchange in the field of educational AI. This approach could lead to greater innovation and advancement in the field. Finally, the results suggest the need for ongoing research to better understand how these tools are used and how they can be optimized. Researchers can capitalize on this trend to explore new areas and approaches within applied AI in education.

Author contributions: RAGC & GC-Q: writing draft article, writing, editing, & critical review of final article, data acquisition, data processing, & final drafting of article; **JFVM:** classification, sorting, integration, & cleaning of data collected from various sources & critical review of final article; & **LAER & CAAD:** data collection, development & design, & critical review of final article. All authors approved the final version of the article.

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Ethics declaration: The authors declared that the study did not require ethics committee approval since it is a review of existing literature.

Declaration of interest: The authors declare no competing interest.

Data availability: Data generated or analyzed during this study are available from the authors on request.

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