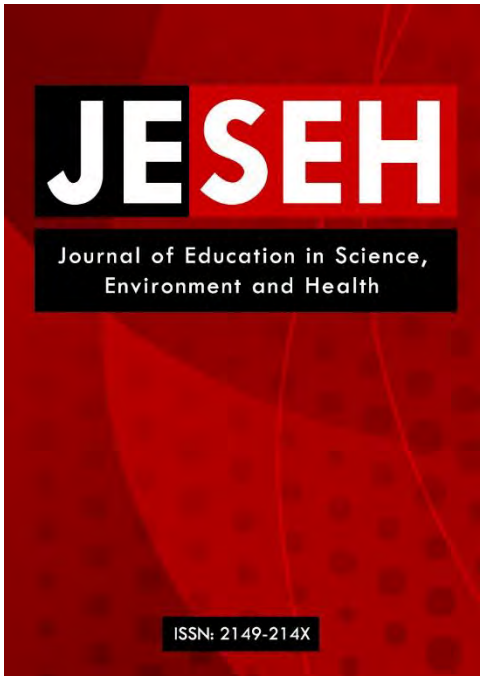

ISSN: 2149-214X

Journal of Education in Science, Environment and Health

www.jeseh.net

Bibliometric Analysis of Studies on the Artificial Intelligence in Science Education with VOSviewer

Hayriye Nevin Genc, Nuriye Kocak
Necmettin Erbakan University

To cite this article:

Genc, H. N. & Kocak, N. (2024). Bibliometric analysis of studies on the artificial intelligence in science education with VOSviewer. *Journal of Education in Science, Environment and Health (JESEH), 10*(4), 183-195. https://doi.org/10.55549/jeseh.756

JESEH
Journal of Education in Science, Environment and Health
Volume 10, Issue 4, 2024
https://doi.org/10.55549/jeseh.756

Bibliometric Analysis of Studies on the Artificial Intelligence in Science Education with VOSviewer

Hayriye Nevin Genc, Nuriye Kocak

Article Info

Article History

Published:
01 October 2024

Received:
14 May 2024

Accepted:
21 August 2024

Keywords

Artificial intelligence, Bibliometric analysis, Science education, VOSviewer

Abstract

Understanding the trends and developments in artificial intelligence research in science education, which has rapidly advanced in recent years, is crucial for technological innovations and applications in education. Therefore, this study examines research on artificial intelligence in science education conducted between 2019 and 2023 (the last five years) through bibliometric analysis, utilizing the Web of Science database. VOSviewer was used for the analysis. As a result of scanning the Web of Science database under these criteria, 867 studies were identified. Analyzing the distribution of these 867 publications by year reveals a concentration in 2023 and 2022. In terms of publication distribution by country, the leading contributors were the USA, China and Australia. The most prolific authors were identified as D. Gasevic, Z. Xiaoming and S. S. Oyelere. Regarding the number of documents and citations in journals, "Computers & Education" ranked first. The most cited used keywords were "Machine Learning" and "Artificial Intelligence", followed by "Learning Analytics", "Data Science" and "Higher Education". The findings illuminate recent research on artificial intelligence in science education. This study is expected to assist researchers in identifying trends within the field and to provide guidance for future studies.

Introduction

Artificial intelligence (AI) can be defined as the development and application of systems that are capable of thinking, learning, and making decisions in a manner similar to human intelligence (Fogel, 2022). It aims to imitate some aspects of human intelligence by utilising computer science, psychology, philosophy and other disciplines. Nowadays, AI finds widespread use in areas such as healthcare, finance, transportation, education, and entertainment (Mukhamediev et al., 2022).

The relationship between AI and educational systems is becoming increasingly significant (Chen et al., 2022). AI stands out as a technology with the potential to transform educational processes (Jaiswal & Arun, 2021). For instance, AI can create personalized educational programs tailored to each individual's learning style and pace by analyzing student data. Therefore, it helps students learn more effectively (Arslan, 2020; Chassignol et al., 2018). Educational institutions can leverage AI-based systems to collect and analyze large datasets. This advancement enables teachers and administrators to gain a better understanding of student performance and adjust educational strategies accordingly (Buluş & Elmas, 2024). Additionally, AI facilitates the development of innovative tools such as virtual teachers and intelligent learning platforms. These tools enable students to learn in an interactive environment. Consequently, AI exerts a substantial impact on educational systems, making learning processes more efficient and effective (Khosravi, 2022; Schiff, 2021; Ulukök Yıldırım & Sönmez, 2024; Xuesong et al., 2021).

In recent years, AI has increasingly been utilized in science education. A large number of studies have explored the application of AI in various aspects of science education, including teaching, learning, assessment, and curriculum development (Akhmadieva et al., 2023; Al Darayseh, 2023; AlKanaan, 2022; Holmes & Tuomi, 2022; Kalogiannakis et al., 2021; Swiecki et al., 2022; Xu & Ouyang, 2022). AI is being applied in diverse ways to enrich students' learning experiences in science classes and to enhance the educational processes of teachers. AI-based simulation software helps students to better understand complex science concepts. For example, in science laboratory courses, AI applications enable students to transfer their theoretical knowledge to practice by conducting virtual experiments (Park et al., 2023). Interactive applications and games that use AI can make the teaching of scientific concepts more engaging and comprehensible (Dimitriadou & Lanitis, 2023). AI also provides virtual teachers that assist students in question answering and guiding their learning processes. Through these applications, students can receive teacher support whenever needed (Chen et al., 2020). In conclusion, AI is effectively utilized in science education across areas such as simulation, interactive learning,

data analysis, and virtual teaching assistants. These applications help students better understand scientific concepts and assist teachers in improving their educational practices (Almasri, 2024).

Due to the increasing number of studies on artificial intelligence, it has become essential to provide a general overview of the research conducted in this area. Bibliometric analysis is the process of quantitatively examining and evaluating scientific publications and citations (Gutiérrez-Salcedo et al., 2018; Ulukök Yıldırım, 2024). It is used to determine the status and trends of scientific activities in a specific field, identify gaps and opportunities in research areas, assess and compare publication performance, visualize collaboration networks among researchers, institutions, and countries, and map scientific fields while tracking their structural changes (Donthu et al., 2021). Bibliometric analysis also examines the number of publications, such as articles, books, and conference papers, published in a particular field or journal, the number of citations, the relationships between related publications, and the frequency and relationships of keywords used in these publications (Akhavan et al., 2016). As a result, bibliometric analysis provides important data for science policy and management by examining the quantitative aspects of scientific communication.

In the field of science education, bibliometric analysis serves as a significant research tool. This analysis reveals innovations and patterns in the field by examining the number of publications related to science education, number of citations, and research trends (Arici et al., 2019). By examining collaborations and interactions among researchers and countries, it uncovers international research networks in science education. Additionally, it is used to identify which topics in science education receive more attention and which research methods are preferred (Comarú et al., 2021). So, these analyses contribute to the development of educational policies and the adoption of innovative approaches in science education.

A bibliometric analysis of studies related to AI can be found in the literature (Al Husaeni et al., 2022; Guo et al., 2024; Kaban, 2023; Khosravi et al., 2023; Lin & Yu, 2024; López-Chila et al., 2024; Oliński et al., 2024; Pradana et al., 2023; Radu et al., 2024; Shang, 2024). For instance, Lin and Yu (2024) reviewed the existing literature on AI chatbots from an educational perspective and aimed to address research gaps. Guo et al. (2024), conducted a bibliographic analysis encompassing 6843 publications over the past decade to identify trends in AI research within the field of education and to understand its development. Khosravi et al. (2023) focused specifically on ChatGPT, performing a bibliometric analysis of the scientific literature concerning chatbots. Their study examined sources, countries, author impact, and keywords, concluding that ChatGPT represents the latest trend in the field of chatbots.

Kaban (2023) examined articles on AI in education and employed bibliometric mapping methods to reveal trends in the field of AI in education across various variables. The study presented results related to the most cited publications, trending topics, thematic maps of keywords, and co-occurrence networks. López-Chila et al. (2024) analyzed the current state of AI in higher education to provide a basis for future research. They performed a bibliometric analysis using the Scopus database for the period between 2017 and 2023. Radu et al. (2024) identified the emerging trends, challenges and new opportunities as a result of AI and Competency Based Education. Al Husaeni et al. (2022) examined the application and use of AI chatbots in the field of education. They conducted a data search in the Scopus database using the keywords ‘chatbot’ and ‘education’ for the research period from 2007 to 2024. Shang (2024) reviewed the existing research on ChatGPT in education using bibliometric analysis methods. The data were collected from English-language studies by searching for the terms ‘ChatGPT’ and ‘Education’. A total of 385 documents were analyzed in this study. Pradana et al. (2023) presented a review of existing research on the use of OpenAI's ChatGPT in education, employing both bibliometric analysis and a systematic literature review. Oliński et al. (2024) conducted a bibliometric analysis of ChatGPT, an AI tool proficient in text analysis within the social sciences. By utilizing data obtained from the Scopus database, a comprehensive selection of 814 related publications was made and subsequently analyzed with VOSviewer to investigate co-citations, keyword occurrences, and patterns of international collaboration.

Unlike these studies, the aim of this research is to examine the studies published between 2019 and 2023 (the last five years) regarding the use of AI in science education in detail under headings such as year, author, citation, journal, country, and keywords, in order to reveal relationships. Thus, it is expected to provide researchers with an overview of the current situation and developments in the field and to identify new research opportunities. This study aims to answer the research questions listed below:

1. What is the distribution of relevant publications by year?
2. Which countries are the most prolific in terms of publication output?
3. Who are the most prolific and influential authors in the field?

4. Which authors are most frequently co-cited?
5. What are the most cited journals in the field?
6. What are the distributions and trends of keywords used in the literature?

Method

This study conducts a bibliometric analysis to investigate the current state of international publications in journals indexed in the Web of Science (WoS) database regarding the use of AI in science education. Bibliometric analysis is an approach that quantitatively measures certain indicators by analyzing citations of published works, inter-author relationships, keywords, theoretical and practical topics in a specific field using various statistical techniques. This method allows for monitoring and evaluating the development and advancements within the discipline (Ulukök Yıldırım & Sönmez, 2024). A successful bibliometric study can lay a solid foundation for innovative and meaningful progress in a field, thereby providing researchers with a comprehensive overview, identifying knowledge gaps, generating new research ideas, and positioning their planned contributions within the existing literature.

Purpose and Limitations of the Study

Due to the fact that the current year is not yet completed, publications from 2024 have not been included in the study. The determination of the data to be used in the study as the last five years, the utilization of the WoS database, the application of VOSviewer software for bibliometric analyses, and the focus on selected titles for network mapping in the analyses constitute the limitations of this research.

Data Collection Process

While there are many databases indexing educational research, one of the most widely used databases for various analyses, including bibliometric analyses, is the WoS, which is one of the world's most important scientific citation search and analytical information platforms. For this reason, WoS has been utilized in this study due to its provision of a comprehensive data set across different disciplines, includes of the most influential journals and publications in the field, holds the distinction of being one of the oldest and most widely used databases, provides daily updates, and is compatible with VOSviewer, a widely used program in bibliometric studies, that enables file downloads in the desired format. (Hu et al., 2020; Li, Kazak & Kazak, 2023; Rollins, & Yan, 2018). The study includes only articles due to their status as the most common and representative type of scientific publication, their bibliometric indicators, inclusion of original research findings, comparability, and the ability to be analyzed using bibliometric methods (Atmaca Aksoy, 2024). As of September 3, 2024, a total of 867 studies were identified in the WoS database depended on the search criteria presented in Table 1.

Table 1. Article selection process

Parameter	Details
Database	WoS
Keywords	(“artificial intelligence” OR “AI” OR “AIED” OR “machine learning” OR “intelligent tutoring system” OR “expert system” OR “recommended system” OR “recommendation system” OR “feedback system” OR “personalized learning” OR “adaptive learning” OR “prediction system” OR “student model” OR “learner model” OR “data mining” OR “learning analytics” OR “prediction model” OR “automated evaluation” OR “automated assessment” OR “robot” OR “virtual agent” OR “algorithm” OR “machine intelligence” OR “intelligent support” OR “intelligent system” OR “deep learning” OR “AI education”) and (“science” or “science education”)
Research Area	“Education and Educational Research” OR “Education Scientific Disciplines” OR “Education Special”
Publication Type	Article
Publication Years	2019-2023
Indexes	SCI-EXPANDED, SSCI, A&HCI, ESCI
Languages	English
Date	03 September 2024

Data Analysis

In this study, the bibliographic data of the 867 documents obtained from WoS were imported into VOSviewer (version 1.6.20), a software that allows for the creation and detailed examination of bibliometric maps. The imported format includes publication year, language, journal, title, author, institution, keywords, document type, abstract, and citation count. VOSviewer is a software tool designed for creating, exploring, and visualizing maps derived from bibliometric network data (Van Eck & Waltman, 2010). It can be employed to construct networks consisting of scientific publications, scientific journals, researchers, research institutions, countries, keywords, or terms. The elements in these networks can be connected through co-authorship, co-publication, citation, bibliographic links or co-citation links (Van Eck & Waltman, 2022). In this context, the study identified year, country, journal, citation, co-citation, and keywords. Before each analysis, the relevant data were carefully examined, and essential data cleaning processes were performed. This included the creation of "thesaurus files" for author, journal, and institution names that were written in different languages and scripts, as well as for identical or closely related terms.

Findings

Under this heading, findings related to distribution of publications by year and country, the most influential authors, journals, and the most used keywords are presented.

Distribution of the Number of Studies (2019-2023)

Figure 1 presents the distribution of articles obtained from the WoS database, illustrating the number of publications from 2019 to 2023. The data indicates a clear trend in the annual output of scholarly works, revealing fluctuations in publication rates across these years. This temporal analysis offers significant insights into the changing landscape of research activity within the defined timeframe.

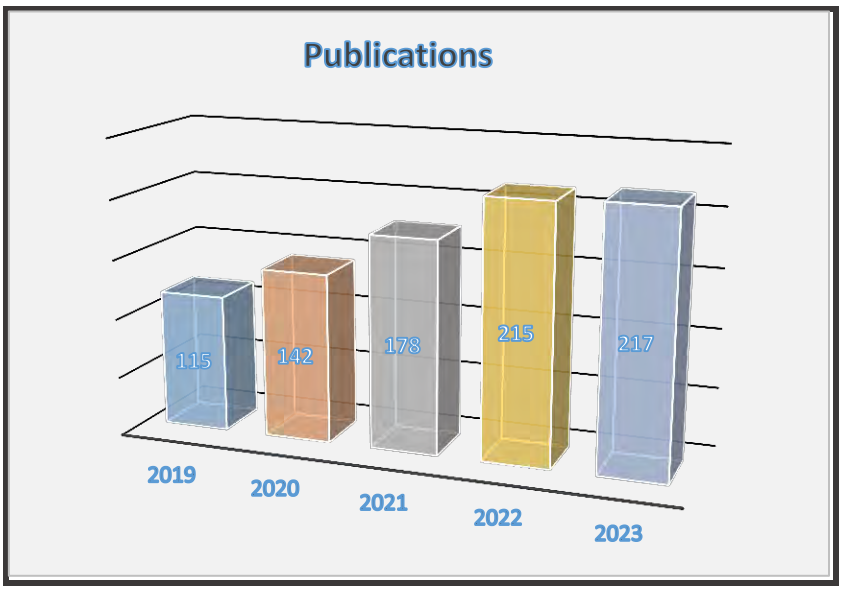

Figure 1. Distribution of publications by year

As can be seen from the Figure 1, studies on AI in science education have increased day by day. In 2023, the number of publications reached the highest level.

A Distribution of Publications by Country

Table 2 presents the geographical distribution of publications. In analyzing the most productive countries in scientific research, a minimum threshold of 10 documents and at least 1 citation was established. This criterion ensures the inclusion of countries with a substantial impact on the scholarly output, facilitating a clearer understanding of global research dynamics.

Table 2. A distribution of publications by ten top countries

Rank	Country/ Region	Number of publications	Citation	TLS
1	USA	273	2896	104
2	China	93	873	43
3	Australia	52	870	19
4	Spain	51	581	11
5	Taiwan	49	577	12
6	Germany	44	534	47
7	Türkiye	40	290	13
8	England	34	561	10
9	Canada	32	543	23
10	Finland	29	618	17

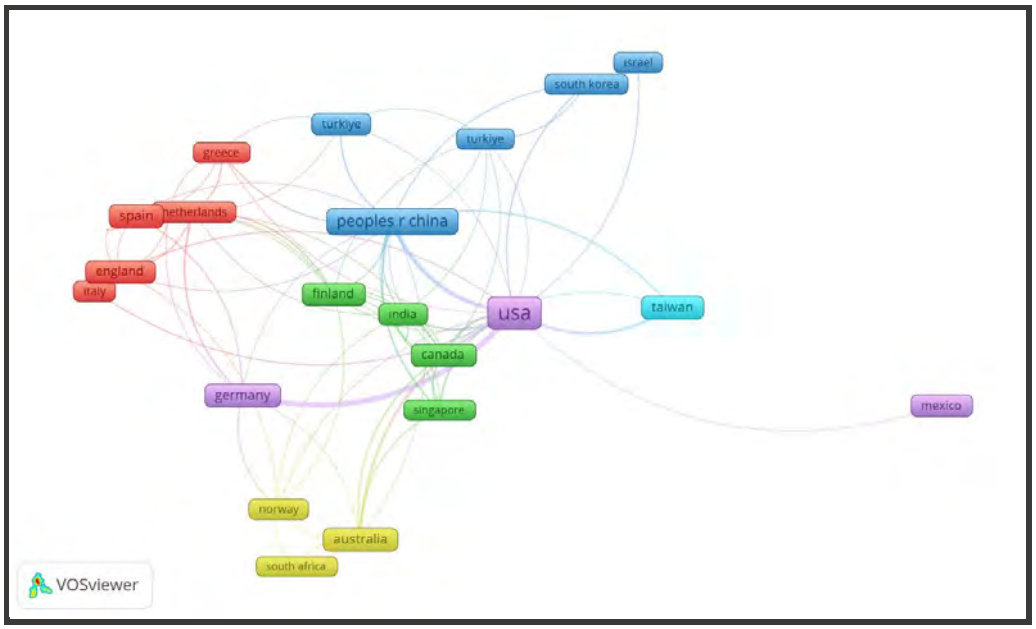

Figure 2. Global collaboration through documents published by country

An analysis was conducted using 24 observation units that exhibit relationships (Figure 2). Six clusters, 76 link and 202 total link strength were identified. The countries with the highest number of citations are the USA (2896 citations), China (873 citations), and Australia (870 citations). In terms of the number of publications, the ranking is as follows: USA (273 publications), China (93 publications), and Australia (52 publications).

Most Influential Researchers in terms of the Number of Citations

A citation network map was created based on the criteria of at least three publications and a minimum of one citation to identify citation networks among authors (see Table 3 and Figure 3).

Table 3. Ranking of the most influential researchers by citation

Rank	Author	Number of publications	Citation	TLS
1	D. Gasevic	7	244	1
2	Z. Xiaoming	10	204	87
3	S. S. Oyelere	7	188	11
4	X. Wanli	7	157	28
5	H-S. Lee	4	156	26
6	C. Xie	7	141	35
7	F. J. Agbo	3	137	6
8	G. Chen	4	127	24
9	G. Zhu	5	111	7
10	I. T. Sanusi	3	98	0

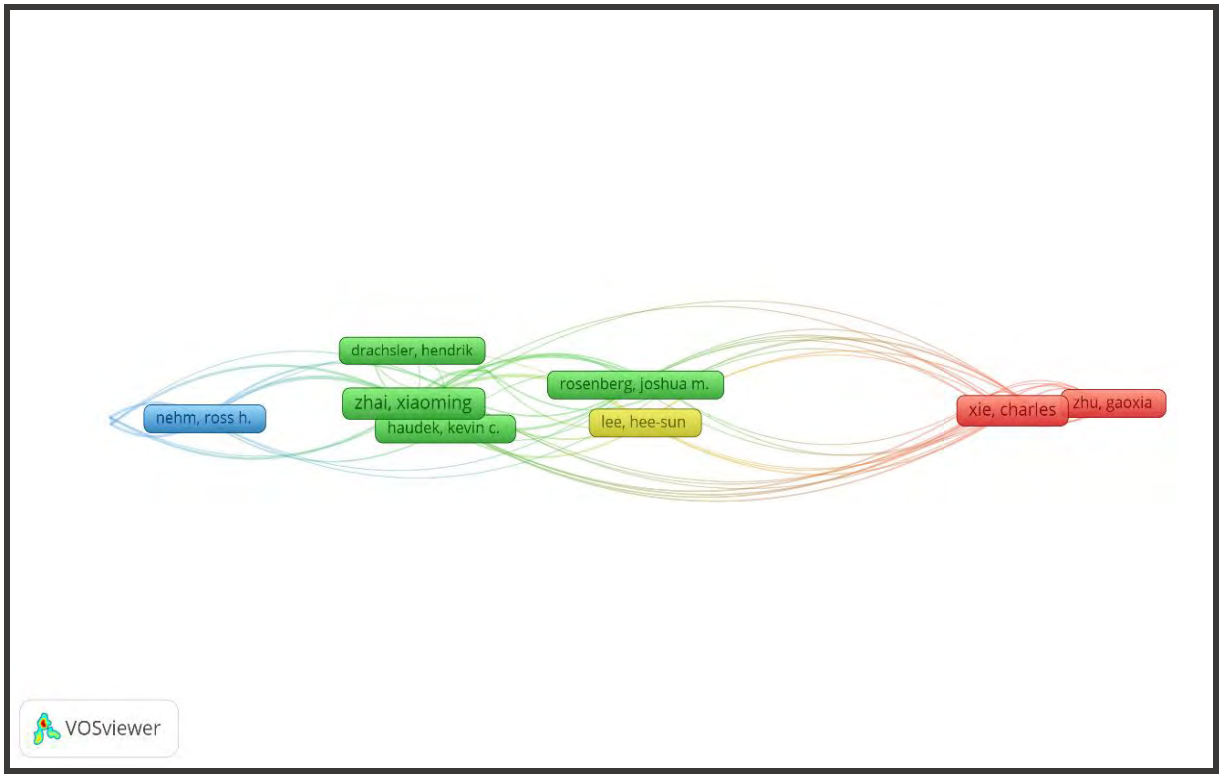

Figure 3. Author citation network

In an analysis conducted on 58 interconnected units, a total of four clusters, 86 link, and total link strength of 237 were identified. The most cited authors are Dragan Gasevic with 244 citations, Zhai Xiaoming with 204 citations, and Solomon Sunday Oyelere with 188 citations. Additionally, 'co-citation' was selected as the type of analysis, with 'cited authors' designated as the analysis unit within the VOSviewer program. A threshold value of 35 was established to minimize clutter in the data visualization. The resulting map is presented in Figure 4.

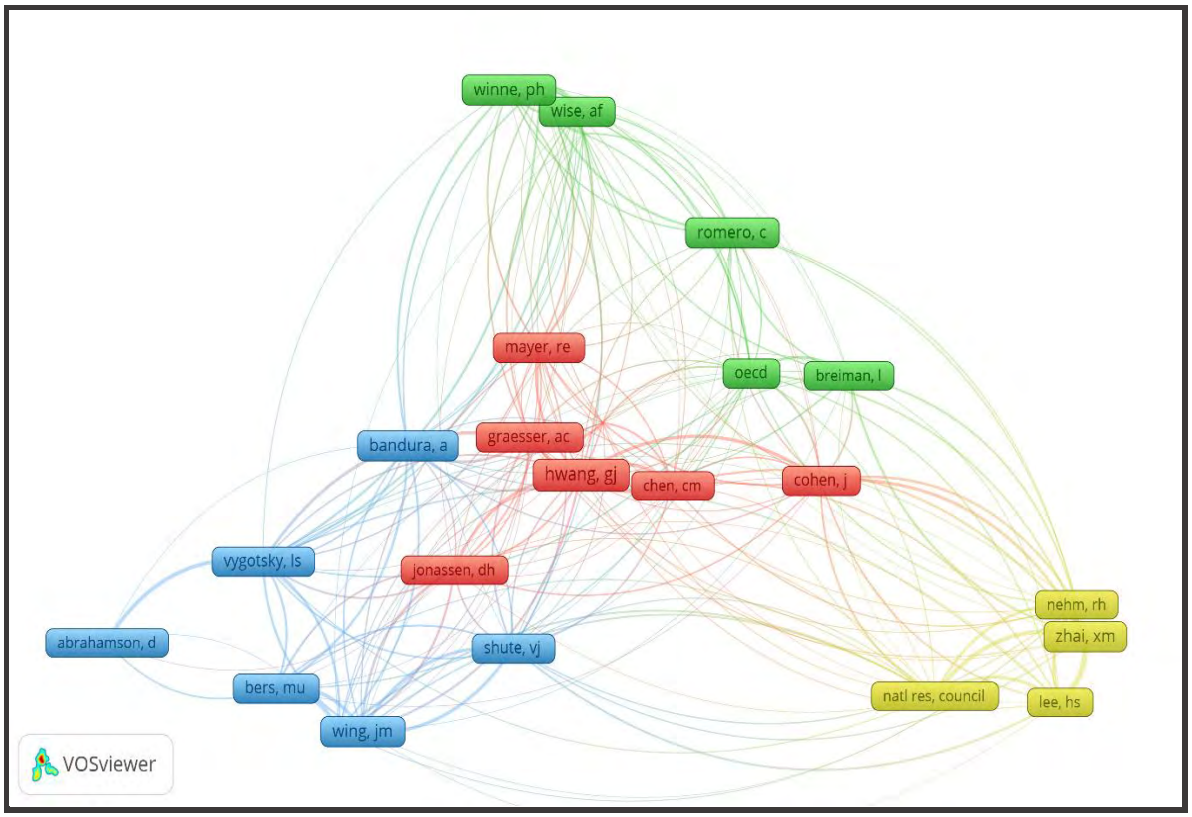

Figure 4. Co-author citation network

Table 4. Ranking of the most influential researchers by co-citation

Rank	Author	Co-Citation	TLS
1	G-J. Hwang	86	139
2	X. M. Zhai	72	284
3	P. H. Winne	67	125
4	J. M. Wing	66	188
5	A. Bandura	65	110
6	C. Romero	65	70
7	D. Gasevic	59	196
8	A. F. Wise	56	142
9	M. U. Bers	55	118
10	OECD	55	99

When the map in Figure 4 and Table 4 are examined, it is seen that there are four different colored clusters related to the common referenced authors. G-J. Hwang is in the center of the names in the red cluster, at the center of the yellow cluster is X. M. Zhai, at the center of the blue cluster is J.M. Wing and at the center of the green cluster is P.H. Winne. G-J. Hwang (86 co-citations), X. M. Zhai (72 co-citations), P. H. Winne (67 co-citations), J. M. Wing (66 co-citations) and A. Bandura (65 co-citations) are highly cited authors.

The Most Influential Journals in Terms of the Number of Citations

Journals with a minimum of ten publications were included in the analysis. A citation analysis was conducted to identify the most influential publications in the field. The results indicated that 21 out of 232 journals published ten or more studies on the topic (Figure 5). Table 5 presents the top ten most influential journals.

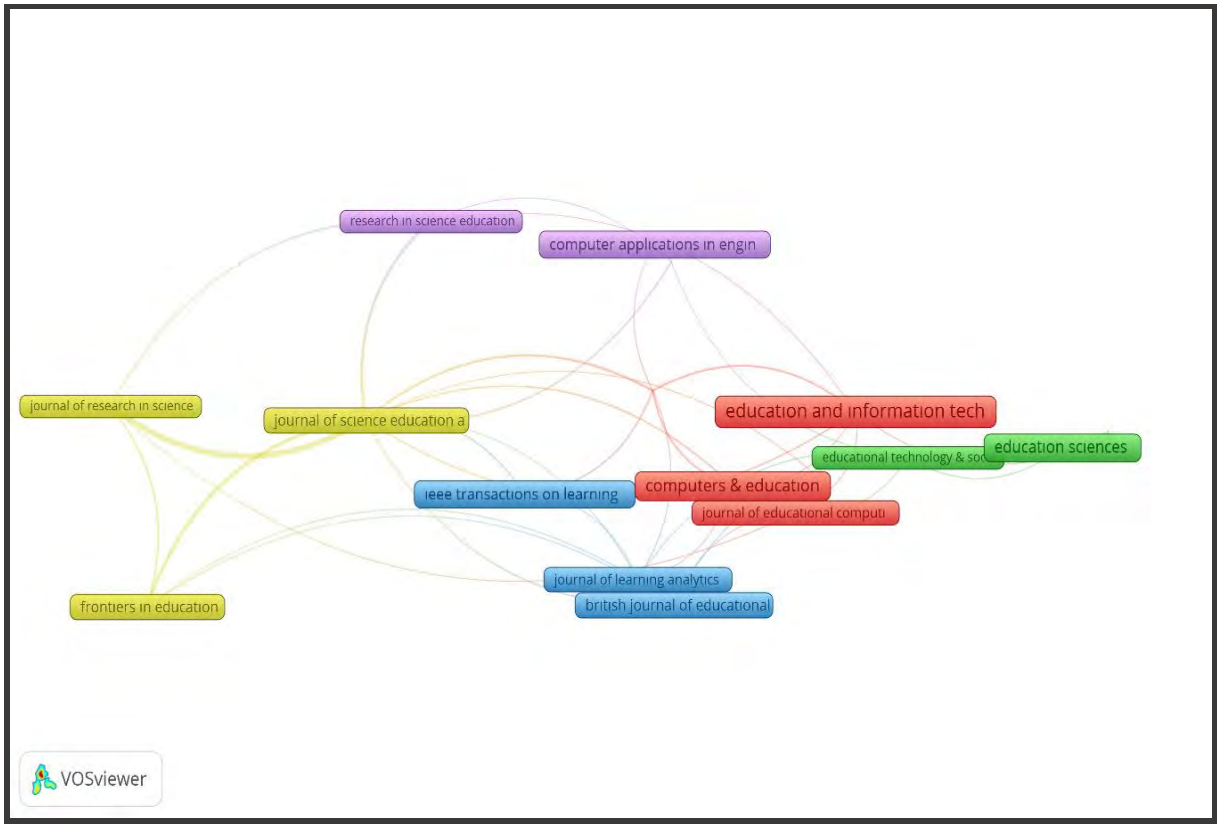

Figure 5. Journal network

According to the findings in Table 5, the journals "Computers & Education" journal is in first place with 90 articles. "Education and Information Technologies" ranks second with 60 publications. It is followed by the "Education Sciences" with 34 articles. The journal with the highest TLS value is "Journal of Science Education and Technology". The most cited journal is "Computers & Education" with 1131 citations.

Table 5. The most influential journals

Rank	Journals	Number of publications	Citation	TLS
1	Computers & Education	90	1131	9
2	Education and Information Technologies	60	588	9
3	Journal of Science Education and Technology	23	535	61
4	British Journal of Educational Technology	22	387	10
5	Education Sciences	34	318	2
6	IEEE Transactions on Learning Technologies	27	266	5
7	Etr&D-Educational Technology Research and Development	19	243	14
8	Journal of Educational Computing Research	12	230	6
9	Computer Applications in Engineering Education	26	210	2
10	Interactive Learning Environments	19	209	6

Keyword Analysis and Trending Topics

A total of 2661 keywords were used in 867 publications regarding AI in science education. The minimum threshold number of a keyword in VOSviewer is set to 15. As a result of the analysis, 20 keywords, 4 clusters, 101 link and 286 total link strength that met the usage criteria emerged. Table 6 shows the top ten most influential keywords.

Table 6. The most influential keywords

Rank	Keyword	Occurrences	TLS
1	Machine Learning	103	86
2	Artificial Intelligence	103	67
3	Learning Analytics	85	53
4	Data Science	53	70
5	Higher Education	44	41
6	e-Learning	36	26
7	Education	34	41
8	Computational Thinking	32	19
9	Computer Science Education	31	14
10	Data Science Applications in Education	29	5

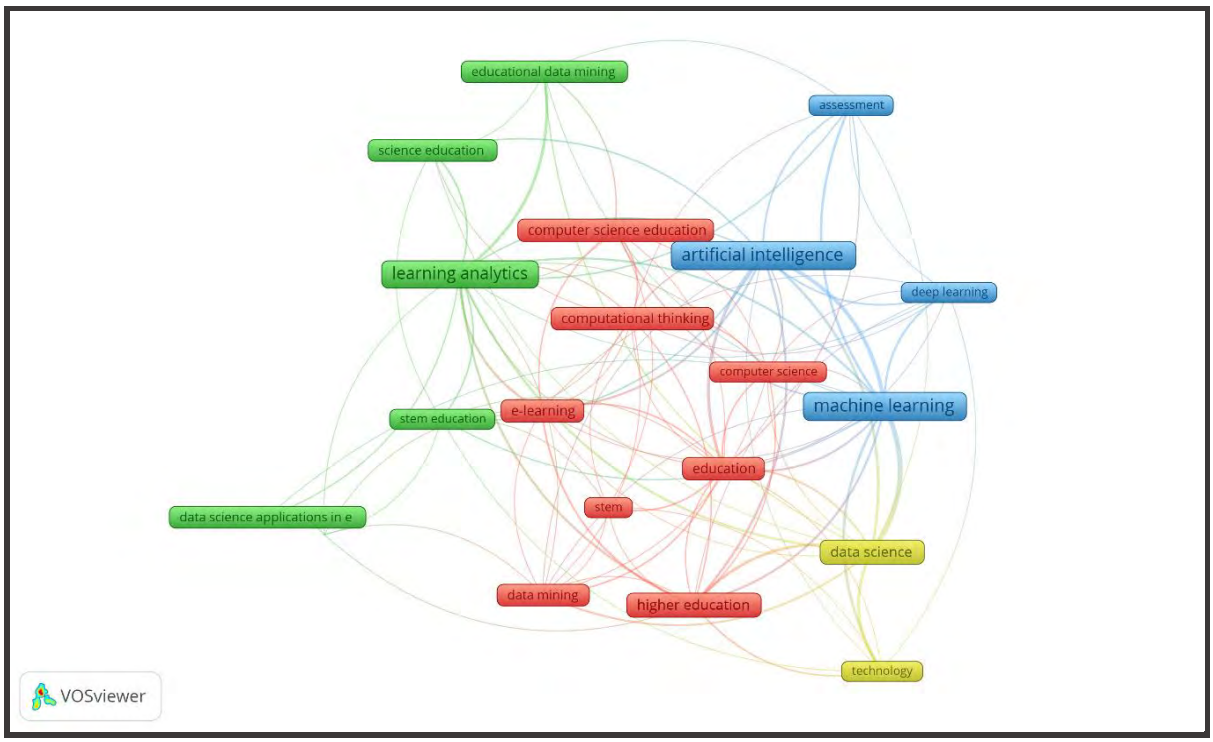

Figure 6. Keywords network

As shown in Figure 6, the first red cluster contains the words computational thinking, computer science, computer science education, data mining, e-learning, education, higher education and stem. The second cluster, colored green, includes adaptive learning, data science applications in education, educational data mining, learning analytics, science education and stem education. The words artificial intelligence, assessment, deep learning and machine learning are included in the blue cluster. The fourth cluster is yellow. The prominent keywords in this cluster are data science and technology. Machine learning, artificial intelligence, learning analytics are the most frequently used keywords.

Conclusion and Discussion

Publications related to AI in science education were retrieved from WoS and analyzed in an objective and comprehensive manner. The study comprises articles published in English. A total of 867 articles indexed in the WoS database on the topic of AI in science education from 2019 to 2023 (the past five years) were contained in the bibliographic analysis.

The results of this study show that the total of AI studies in science education has increased significantly, especially in recent years. An examination of the distribution of 867 publications related to AI by publication year reveals that the highest output occurred in 2023 and 2022. Notably, approximately half of the articles (49.8%) were published in the last two years. The increase in the number of publications in recent years is attributed to the rapid advancement of technology and the growing importance of AI applications in education. It is anticipated that research in the field of AI within science education will continue to rise in the future (Jia, Sun, & Looi, 2024; Yılmaz, 2024). Talan (2021), examined the articles between the years 2001-2022 in the bibliometric analysis of studies on AI in education. publications. Talan concluded that the number of publications between 2001 and 2004 was low, but there was a notable increase in publications in the subsequent years, with studies published after 2015 accounting for 60% of the total publications. Kaban (2023), examined all studies related to AI in education scanned in the WoS database. As a result of bibliometric analysis, the number of publications started to climb after 2004, and there was a severe increase in 2019. Lopez-Chila et al. (2024) examined 870 articles sourced from the Scopus database related to AI in higher education from 2017 to 2023. Their study found that the number of publications recorded up to 2022 exhibited a continuous increase over the years, with a particularly pronounced rise following the release of ChatGPT, OpenAI's generative AI product, in November 2022.When examining the distribution of studies by country, the USA, China and Australia emerge as notable contributors. The literature indicates that similar findings have been reported, with the USA leading in publications on educational AI (Chen, Xie & Hwang, 2020; Moreno-Guerrero et al., 2020; Song & Wang, 2020).

The top three journals that publish the most articles are "Computers & Education," "Education and Information Technologies" and "Education Sciences" with "Computers & Education" being the most cited journal. This journal is recognized as one of the leading scientific publications with a notable academic impact in the field of educational technology. It is indexed in numerous international databases, particularly the Social Sciences Citation Index (SSCI). Talan (2021) identified “Computers & Education” and the “International Journal of Emerging Technologies in Learning” as the most frequently published journals. Analyzing citation metrics, he found that “Computers & Education”, “IEEE Transactions on Education” and the “Educational Technology Society” emerged as the most popular journals based on citations per article. Similarly, Moreno-Guerrero et al. (2020) examined the scientific development of educational AI in the WoS and also noted that “Computers & Education” ranked among the top publishing journal. Additionally, Chen, Xie and Hwang (2020) analyzed studies on AI in education across various dimensions, including grants, conferences, journals, software tools, institutions, and researchers. Their findings revealed that the majority of published research in this area consisted of conference papers, with “Computers & Education” and the “International Journal of Engineering Education” standing out in terms of scientific publications. Likewise, Kaban (2023) concluded that the highest number of articles on AI in education were published in “Education and Information Technologies” and “Computers & Education”.

Analyzing the keywords used by authors in publications is a vital method for identifying trending topics and providing insights for researchers engaged in related work (Song et al., 2019). Keyword analysis facilitates a swift determination of the topic and focus of a given publication. Upon examining the keywords, it was found that "machine learning" "artificial intelligence" and "learning analytics" are the most frequently used terms. In the study conducted by Chen, Xie, and Hwang (2020), the most commonly employed keywords related to AI in education were identified as "education", "machine learning", "robotics", "artificial intelligence", "deep learning", "system" and "educational robotics". Guo et al. (2024) performed a bibliometric analysis of Artificial

Intelligence in Education (AIED) to explore the current status and key research trends over the past decade. They categorized the results into three aspects: AIED technology, applications, and subject domain outcomes. Jia, Sun, & Looi (2024) investigated the trends and research focuses of AI in the early stages of education. Their findings highlighted the most prominent keywords and their associated themes in AI in science education, such as science education, robotics, artificial intelligence, and machine learning. In the bibliometric study conducted by Talan (2021) in the field of AI in education, it was observed that keywords such as artificial intelligence, intelligent tutoring systems, machine learning, deep learning, and higher education are positioned at the center of the keyword network map.

When examining authors who have conducted research in the field of AI in science education, it is evident that the most cited authors Dragan Gasevic, Zhai Xiaoming and Solomon Sunday Oyelere. It can be stated that these authors have made important contributions to the field of AI in science education and shaped its direction. It is noteworthy that the number of publications and citations for these three authors are almost proportional. Additionally, they rank among the top three in terms of total link strength. Upon reviewing Dragan Gasevic's works, it is evident that his highly cited and valuable article (2020), "Vision, Challenges, Roles, and Research Issues of AI in Education" addresses the critical roles of AI in education and proposes ten research topics, thereby providing a valuable resource for those entering this field. Zhai Xiaoming has conducted studies across various domains, including education, science education, and artificial intelligence, contributing to the field by delineating the current state of artificial intelligence, key research topics, and educational outcomes over the past decade. His work offers researchers a comprehensive overview of this promising area, providing insights for future research topics and directions. Solomon Sunday Oyelere's research emphasizes the importance of utilizing AI in education and offers recommendations. He highlights the crucial role teachers play in encouraging the next generation of students to engage in AI-supported learning and preparing them for human-AI collaboration in the future.

This bibliometric analysis of AI in science education has revealed a significant increase in the scientific literature regarding the use of AI technologies in this field in recent years. The studies have become increasingly diverse and detailed, indicating that AI technologies are enhancing teaching and learning experiences. However, this field is still relatively new, and understanding the existing research can provide insights into how to optimize the integration of AI into science education. By examining the results of this bibliometric study, researchers will gain information about the most active and collaborative authors in the last five years, the most cited articles, the most frequently used keywords, and the journals that have published the highest number of articles in this area. Equipped with this information, researchers can plan their studies accordingly, significantly contributing to the advancement and development of AI in science education.

In future studies, alongside WoS, other databases such as Scopus and Google Scholar could also be systematically reviewed to expand the search data. Collaborations could be established with prominent authors based on citation and publication counts, and planned research could focus on less commonly used keywords in addition to the highlighted ones, contributing to the field through new studies.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

Acknowledgements or Notes

On behalf of authors, the corresponding author states that there is no conflict of interest

References

Akhavan, P., Ebrahim, N. A., Fetrati, M. A., & Pezeshkan, A. (2016). Major trends in knowledge management research: A bibliometric study. *Scientometrics, 107*, 1249–1264. https://doi.org/10.1007/s11192-016-1938-x

Akhmadieva, R. S., Udina, N. N., Kosheleva, Y. P., Zhdanov, S. P., Timofeeva, M. O., & Budkevich, R. L. (2023). Artificial intelligence in science education: A bibliometric review. *Contemporary Educational Technology, 15*(4), ep460. https://doi.org/10.30935/cedtech/13587

Al Darayseh, A. (2023). Acceptance of artificial intelligence in teaching science: Science teachers' perspective. *Computers and Education: Artificial Intelligence, 4*, 100132. https://doi.org/10.1016/j.caeai.2023.100132

Al Husaeni, D., Haristiani, N., Wahyudin, W., & Rasim, R. (2022). Chatbot artificial intelligence as educational tools in science and engineering education: A literature review and bibliometric mapping analysis with its advantages and disadvantages. *ASEAN Journal of Science and Engineering, 4*(1), 93-118. https://doi.org/10.17509/ajse.v4i1.67429

AlKanaan, H. M. N. (2022). Awareness regarding the implication of artificial intelligence in science education among pre-service science teachers. *International Journal of Instruction, 15*(3), 895-912. https://doi.org/10.29333/iji.2022.15348a

Almasri, F. (2024). Exploring the impact of artificial intelligence in teaching and learning of science: A systematic review of empirical research. *Res Sci Educ*, *54*, 977–997. https://doi.org/10.1007/s11165-024-10176-3

Arici, F., Yildirim, P., Caliklar, Ş., & Yilmaz, R. M. (2019). Research trends in the use of augmented reality in science education: Content and bibliometric mapping analysis. *Computers & Education*, *142*, 103647. https://doi.org/10.1016/j.compedu.2019.103647.

Arslan, K. (2020). Artificial intelligence and applications in education. *Batı Anadolu Eğitim Bilimleri Dergisi, 11*(1), 71–88.

Atmaca-Aksoy, A. C. (2024). Using technology in science education: A bibliometric analysis. *Journal of Education in Science, Environment and Health (JESEH), 10*(3), 230-244. https://doi.org/10.55549/jeseh.730

Buluş, B., & Elmas, R. (2024). Yapay zeka uygulamalarının kimya eğitiminde kullanımı alternatif araçlar. *Turkiye Kimya Dernegi Dergisi Kisim C: Kimya Egitimi*, *9*(1), 01-28. https://doi.org/10.37995/jotcsc.1366999

Chassignol, M., Khoroshavin, A., Klimova, A., & Bilyatdinova, A. (2018). Artificial Intelligence trends in education: A narrative overview. *Procedia Computer Science*, *136*, 16-24. https://doi.org/10.1016/j.procs.2018.08.233.

Chen, L., Chen, P., & Lin, Z. (2020). Artificial intelligence in education: A review. *IEEE, 8*, 75264-75278. https://doi.org/10.1109/ACCESS.2020.2988510

Chen, X., Xie, H., & Hwang, G. J. (2020). A multi-perspective study on artificial intelligence in education: Grants, conferences, journals, software tools, institutions, and researchers. *Computers and Education: Artificial Intelligence, 1,* 100005. https://doi.org/10.1016/j.caeai.2020.100005.

Chen, X., Zou, D., Xie, H., Cheng, G., & Liu, C. (2022). Two decades of artificial intelligence in education: Contributors, collaborations, research topics, challenges, and future directions. *Educational Technology & Society*, *25*(1), 28–47. https://www.jstor.org/stable/48647028

Comarú, M. W., Lopes, R. M., Braga, L. A. M., Batista Mota, F., & Galvão, C. (2021). A bibliometric and descriptive analysis of inclusive education in science education. *Studies in Science Education*, *57*(2), 241–263. https://doi.org/10.1080/03057267.2021.1897930

Dimitriadou, E., & Lanitis, A. (2023). A critical evaluation, challenges, and future perspectives of using artificial intelligence and emerging technologies in smart classrooms. *Smart Learn Environ, 10*, 12. https://doi.org/10.1186/s40561-023-00231-3

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, *133*, 285-296. https://doi.org/10.1016/j.jbusres.2021.04.070.

Fogel, D. B. (2022). *Defining artificial intelligence*. Machine Learning and the City: Applications in Architecture and Urban Design, 91–120. https://doi.org/10.1002/9781119815075.ch7

Guo, S., Zheng, Y., & Zhai, X. (2024). Artificial intelligence in education research during 2013–2023: A review based on bibliometric analysis. *Educ Inf Technol*. https://doi.org/10.1007/s10639-024-12491-8

Gutiérrez-Salcedo, M., Martínez, M. Á., Moral-Munoz, J. A., Herrera-Viedma, E., & Cobo, M. J. (2018). Some bibliometric procedures for analyzing and evaluating research fields. *Appl Intell*, *48*, 1275–1287. https://doi.org/10.1007/s10489-017-1105-y

Holmes, W., & Tuomi, I. (2022). State of the art and practice in AI in education. *European Journal of Education, 57*(4), 542-570. https://doi.org/10.1111/ejed.12533

Hu, G., Wang, L., Ni, R., & Liu, W. (2020). Which h-index? An exploration within the Web of Science. *Scientometrics*, *123*(3), 1225-1233. https://doi.org/10.1007/s11192-020-03425-5

Hwang, G-J., Xie, H., Wah, B. W., & Gašević, D. (2020). Vision, challenges, roles and research issues of artificial intelligence in education. *Computers and Education: Artificial Intelligence*, *1*, 100001. https://doi.org/10.1016/j.caeai.2020.100001

Jaiswal, A., & Arun, C. J. (2021). Potential of artificial intelligence for transformation of the education system in India. *International Journal of Education and Development using Information and Communication Technology (IJEDICT)*, *17*(1), 142-158.

Jia, F., Sun, D., & Looi, Ck. (2024). Artificial intelligence in science education (2013–2023): Research trends in ten years. *J Sci Educ Technol*, *33*, 94–117. https://doi.org/10.1007/s10956-023-10077-6

Kaban, A. (2023). Artificial intelligence in education: A science mapping approach. *International Journal of Education in Mathematics, Science, and Technology (IJEMST)*, *11*(4), 844-861. https://doi.org/10.46328/ijemst.3368

Kalogiannakis, M., Papadakis, S., & Zourmpakis, A. I. (2021). Gamification in science education. A systematic review of the literature. *Education Sciences, 11*(1), 22. https://doi.org/10.3390/educsci11010022

Kazak, M., & Kazak, G. (2023). Bibliometric analysis of health tourism studies with Vosviewer. *Journal of Healthcare Management and Leadership (JOHMAL)*, *1*, 34-45. https://doi.org/10.35345/johmal.1253318

Khosravi, H., Shafie, M. R., Hajiabadi, M., Raihan, A. S., & Ahmed, I. (2023). Chatbots and ChatGPT: A bibliometric analysis and systematic review of publications in Web of Science and Scopus databases. arXiv preprint arXiv:2304.05436.

Khosravi, H., Shum, S. B., Chen, G., Conati, C., Tsai, Y-S., Kay, J., Knight, S., Martinez-Maldonado, R., Sadiq, S., & Gašević, D. (2022). Explainable artificial intelligence in education. *Computers and Education: Artificial Intelligence*, *3*, 100074. https://doi.org/10.1016/j.caeai.2022.100074.

Li, K., Rollins, J., & Yan, E. (2018). Web of Science use in published research and review papers 1997-2017: A selective, dynamic, cross-domain, content-based analysis. *Scientometrics*, *115*, 1-20. https://doi.org/10.1007/s11192-017-2622-5

Lin, Y., & Yu, Z. (2024). A bibliometric analysis of artificial intelligence chatbots in educational contexts. *Interactive Technology and Smart Education*, *21*(2), 189-213. https://doi.org/10.1108/ITSE-12-2022-0165

Lopez-Chila, R., Llerena-Izquierdo, J., Sumba-Nacipucha, N., & Cueva-Estrada, J. (2024). Artificial ıntelligence in higher education: An analysis of existing bibliometrics. *Educ Sci*, *14*, 47. https://doi.org/10.3390/educsci14010047

Moreno-Guerrero, A. J., López-Belmonte, J., Marín-Marín, J. A., & Soler-Costa, R. (2020). Scientific development of educational artificial intelligence in web of science. *Future Internet, 12*(8), 1-17. https://doi.org/10.3390/fi12080124

Mukhamediev, R. I., Popova, Y., Kuchin, Y., Zaitseva, E., Kalimoldayev, A., Symagulov, A., Levashenko, V., Abdoldina, F., Gopejenko, V., & Yakunin, K. (2022). Review of artificial intelligence and machine learning technologies: Classification, restrictions, opportunities and challenges. *Mathematics*, *10*, 2552. https://doi.org/10.3390/math10152552

Oli´nski, M., Krukowski, K., & Sieci´nski, K. (2024). Bibliometric overview of ChatGPT: New perspectives in social sciences. *Publications*, *12*, 9. https://doi.org/10.3390/publications12010009

Park, J., Teo, T. W., Teo, A., Chang, J., Huang, J. S., & Koo, S. (2023). Integrating artificial intelligence into science lessons: Teachers' experiences and views. *IJ STEM Ed*, *10*, 61. https://doi.org/10.1186/s40594-023-00454-3

Pradana, M., Elisa, H. P., & Syarifuddin, S. (2023). Discussing ChatGPT in education: A literature review and bibliometric analysis. *Cogent Education*, *10*(2), 2243134. https://doi.org/10.1080/2331186X.2023.2243134

Radu, C., Ciocoiu, C. N., Veith, C., & Dobrea, R. C. (2024). Artificial intelligence and competency-based education: A bibliometric analysis. *Amfiteatru Economic*, *26*(65), 220-240. https://doi.org/10.24818/EA/2024/65/220

Schiff, D. (2021). Out of the laboratory and into the classroom: The future of artificial intelligence in education. *AI & Soc*, *36*, 331–348. https://doi.org/10.1007/s00146-020-01033-8

Shang, L. (2024). Bibliometric analysis of potential themes and trend development of ChatGPT in the field of education. *Advances in Educational Technology and Psychology*, *8*, 49-55. http://dx.doi.org/10.23977/aetp.2024.080308.

Song, P., & Wang, X. (2020). A bibliometric analysis of worldwide educational artificial intelligence research development in recent twenty years. *Asia Pacific Education Review*, *21*(3), 473–486. https://doi.org/10.1007/S12564-020-09640-2/FIGURES/3

Song, Y., Chen, X., Hao, T., Liu, Z., & Lan, Z. (2019). Exploring two decades of research on classroom dialogue by using bibliometric analysis. *Computers & Education*, *137*, 12–31. https://doi.org/10.1016/J.COMPEDU.2019.04.002

Swiecki, Z., Khosravi, H., Chen, G., Martinez-Maldonado, R., Lodge, J. M., Milligan, S., Selwyn, N., & Gašević, D. (2022). Assessment in the age of artificial intelligence. *Computers and Education: Artificial Intelligence, 3*, 100075. https://doi.org/10.1016/j.caeai.2022.100075

Talan, T. (2021). Artificial intelligence in education: A bibliometric study. *International Journal of Research in Education and Science*, *7*(3), 822–837. https://doi.org/10.46328/ijres.2409

Ulukök Yıldırım, Ş., & Sönmez, D. (2024). A bibliometric look at eye tracking research in video-based learning. *Van Yüzüncü Yıl University Journal of Education, 21*(2), 378-400. https://doi.org/10.33711/yyuefd.1378898

Ulukök Yıldırım, Ş. (2024). Trends in planetarium research: A bibliometric analysis. *Millî Eğitim*, *53*(241), 31-56. https://doi.org/10.37669/milliegitim.1188601

Van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, *84*(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3

Van Eck, N. J., & Waltman, L. (2022). *VOSviewer Manual.* Universiteit Leiden.

Xu, W., & Ouyang, F. (2022). The application of AI technologies in STEM education: A systematic review from 2011 to 2021. *International Journal of STEM Education, 9*(1), 1-20. https://doi.org/10.1186/s40594-022-00377-5

Xuesong, Z., Chu, X., Chai, C. S., Jong, M. S. Y., Istenic, A., Spector, M., Liu, J.-B., Yuan, J., & Li, Y. (2021). A review of artificial intelligence (AI) in education from 2010 to 2020. *Complexity*, 18. https://doi.org/10.1155/2021/8812542

Yılmaz, A. (2024). Strengths and weaknesses of teachers' use of artificial intelligence, transhumanism and creativity applications in science education. *International Journal of Eurasia Social Sciences (IJOESS), 15*(55), 17-36. http://dx.doi.org/10.35826/ijoess.4448

Authors Information

Hayriye Nevin Genc
Necmettin Erbakan University
Department of Science Education, A. K. Education Faculty, Konya, Türkiye
Contact e-mail: nnevin85@hotmail.com
ORCID iD https://orcid.org/0000-0003-3240-0714

Nuriye Kocak
Necmettin Erbakan University
Department of Science Education, A. K. Education Faculty, Konya, Türkiye
ORCID iD https://orcid.org/0000-0002-0531-3538