



## Computational mapping analysis of artificial intelligence in education publications: A bibliometric approach utilizing VOSviewer

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**Abstract:** In recent years, interest in the application of AI in education has increased significantly. However, there has been no research explaining the research trends in this area through bibliometric analysis. The goal of this study was to undertake a bibliometric analysis to look at how research on artificial intelligence (AI) in education has evolved. This study used open access bibliometric software for conducting exploratory research and discovering new research directions. It focuses on VOSviewer, a freely available software tool designed to analyze and visualize bibliometric relationships across various variables. Starting with existing examples, the paper then presents an original case study utilizing bibliometrics to investigate the impact of AI on education. Using Scopus data and VOSviewer, this case study analyzes and compares co-occurrence patterns among publications over a decade, showcasing how such software can effectively support preliminary investigations and influence more formal research endeavors.

**Keywords:** artificial intelligence; bibliometric analysis; computational mapping; education; vosviewer

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### Introduction

The global and regional problem related to the research on the application of AI in education lies in the imperative need to understand the full spectrum of its impacts and applications within educational settings. Despite the burgeoning interest and recognition of AI's potential to revolutionize teaching and learning processes (Alam, 2020; Lund et al., 2023), there remains a crucial gap in comprehending its diverse applications and effects in education. The absence of a comprehensive understanding hinders the effective utilization of AI's advantages in educational contexts. Thus, conducting bibliometric analyses becomes vital to systematically explore scholarly papers focused on AI in education, thereby facilitating a deeper understanding of its applications, effects, and potential implications for global and regional educational systems (Hinojo-Lucena, 2019; Hwang, 2021; Prahani, 2022).

While the application of AI in education has shown promising outcomes, it remains essential to conduct a critical evaluation of its impacts and identify any possible limitations. To gain a thorough understanding of the present state of AI implementation in education, it is necessary to undertake a rigorous review of the existing literature and resources. We can identify the important study fields, notable contributors, and significant studies in the subject of AI in education by analyzing bibliometric data, including publication trends, citation patterns, and research collaboration networks (Wilson, 2022).

In this study, we intend to delve into the specific issue of bibliometrically evaluating the effect of AI on education. We will examine the outcomes and implications of adopting AI in educational practices by focusing on scholarly publications from the last ten years. We will also explore the educational domains and levels where AI has been primarily applied.

Previous studies conducted in the last 10 years have offered insightful information about the application of AI in education. To improve personalized learning, adaptive assessments, and educational analytics, researchers have investigated a variety of AI techniques, including natural language processing, machine learning algorithms, and intelligent tutoring systems (Alshaikh & Hewahi, 2021; Chen, 2022; Das et al., 2015; Juhn & Liu, 2020). According to studies, AI-based tools and interventions can enhance student engagement, academic performance, and learning outcomes (Papanastasiou et al., 2019; Tuomi, 2018). Researchers have also looked into privacy issues, ethical concerns, and the role of teachers in AI-driven learning environments.

The use of AI in education has been the subject of numerous scientific investigations over the years. Understanding and integrating the acquired knowledge becomes more crucial as the amount of research in this area keeps growing. Despite the growing use of visual maps in bibliometric analysis, there hasn't been much research done on the subject. Therefore, comprehensive investigations that assess existing research from a variety of perceptions are required. This study's goal is to review research publications on the use of AI in education from a bibliometric standpoint and make recommendations based on the findings. This analysis may involve locating the most important publications and authors, analyzing the relationships between publications and related works, and doing in-depth studies. The study seeks to provide insight into the landscape of research in this area, help professionals find original research subjects, and avoid duplication of research efforts by answering the following questions: (1) What is the distribution of relevant studies by publication year and country?, (2) What are the citation rankings for relevant studies, authors, journals, and institutions?, (3) What patterns emerge in co-citation analysis of authors?, and (4) What patterns emerge in co-occurrence analysis of keywords?

## Method

The research articles utilized in this study were sourced from journals indexed in Scopus. The selection of articles from Scopus was based on its recognized status as a reputable journal indexing platform. In order to gather the research data, the Publish or Perish reference management application was employed, facilitating a comprehensive literature review within the chosen subject area (Zhou et al., 2022). The keywords "artificial intelligence in education" will be used to create thorough search queries. This procedure will guarantee that a variety of pertinent articles are included. To give a current study, the data collection has concentrated on publications over the last ten years. Key bibliographic data has been collected from the chosen articles through data extraction. Authors, publication year, title, journal or conference name, abstracts, and keywords were all included in this data. In order to facilitate future analysis, the retrieved data will next be arranged and organised in an appropriate format.

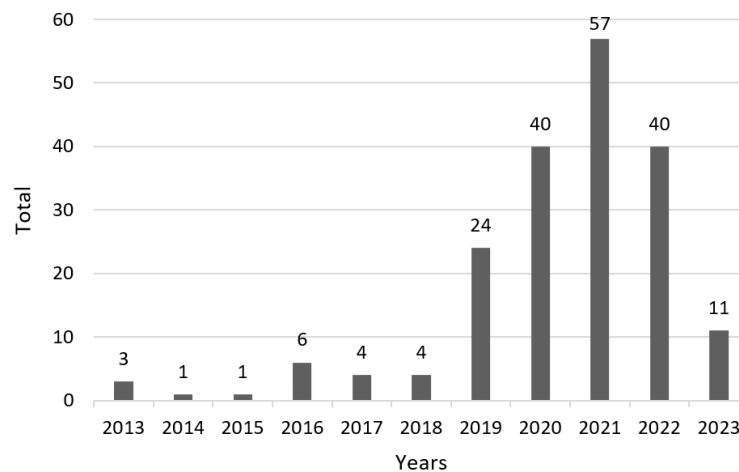
A thorough bibliometric analysis of the collected data has been performed to produce actionable insights. Bibliometric analysis has become an important method in scientific research for understanding and measuring the impact and evolution of scholarly literature across various fields of knowledge (Farooq, 2023). To determine publishing patterns over time, a descriptive bibliometric study of the total number of publications and their distribution across journals and conferences have been carried out (Kokol et al., 2021). Citation analysis has been employed to identify influential articles and authors in the field of AI in education. Co-authorship networks has been analyzed to understand research collaborations and identify key research clusters or groups. Keyword analysis will be performed to identify prevalent themes and topics within the selected publications. Visualization tools and software such as VOSviewer has been utilized to generate visual representations of the bibliometric data, facilitating a better understanding of the relationships and patterns.

The research encompassed several stages, including: (1) Gathering publication data utilizing the publish or perish application, (2) Processing the bibliometric data obtained from the publications using Microsoft Excel, (3) Conducting computational mapping analysis on the bibliometric publication data utilizing the VOSviewer application, (4) Analyzing the results of the computational mapping analysis.

## Results and Discussion

### *Distribution of Publications by Years and Country*

Initially, the study focused on analyzing the distribution of studies published in the Scopus database over the years. The obtained results are depicted in Figure 1.



**Figure 1. Distribution of Publications by Years**

Figure 1 illustrates the development of research on AI in education over the past 10 years, from 2013 to 2023, as published in Scopus. It can be observed that research on AI in education initially experienced a decline for the first 3 years, followed by an increase in the fourth year, and then another decline for the next 2 years. In 2019, there was a significant increase in research on this topic, which continued until 2021, but then decreased again. As of June 2023, there were only 11 research articles published. Table 1 shows the citation metrics of the articles obtained from Publish or Perish.

**Table 1. Citation Metrics**

Metrics	Data
Publication years	2013-2023
Citation years	10 (2013-2023)
Papers	191
Citations	5396
Cites/year	539.60
Cites/paper	28.25
Authors/paper	1.00
h-index	36
g-index	66
hI, norm	36
hI, annual	3.60
hA-index	23

*Citation Analysis (Journal, Author, Institution and Document)*

The Scopus database was then used to analyse the citations for journals with the highest number of publications in the field. The relevant information gleaned from this investigation is shown in Table 2.

**Table 2. Journal Distribution of Publications and Number of Citations**

Journal	Number of articles	Number of Citations	Number of citations per research
Computers and Education: Artificial Intelligence	18	759	42.17
Sustainability (Switzerland)	6	121	20.17
Advances in Intelligent Systems and Computing	5	44	8.80
Education Sciences	4	109	27.25
IEEE Access	4	267	66.75
International Journal of Artificial Intelligence in Education	4	402	100.50
Procedia Computer Science	4	184	46.00
Academic Radiology	3	59	19.67
BMC Medical Education	3	91	30.33
Education and Information Technologies	3	124	41.33
Educational Technology and Society	3	68	22.67
Frontiers in Psychology	3	75	25.00
International Journal of Educational Technology in Higher Education	3	484	161.33
International Journal of Emerging Technologies in Learning	3	17	5.67
JMIR Medical Education	3	128	42.67
Journal of Intelligent and Fuzzy Systems	3	31	10.33
Journal of Physics: Conference Series	3	17	5.67
Mathematical Problems in Engineering	3	34	11.33
Nurse Education in Practice	3	73	24.33

The authors of the research articles were examined using Scopus citation information. The number of articles and citations for the most prolific and well-respected authors in the subject are shown in Table 3. According to the number of citations, the table lists the top nine writers who have at least two works published in the pertinent references. It is clear from the table that in terms of output and influence, G.J. Hwang, X. Chen, and S. O'Connor stand out.

**Table 3. Author Rankings**

Author	Institution	Country	Number of articles	Number of citations
G.J. Hwang	National Taiwan University of Science and Technology	Taiwan	3	291
X. Chen	The Education University of Hong Kong	Hong Kong Special Administrative Region	3	258
S. O'Connor	The University of Manchester	United Kingdom	3	73
F. Ouyang	Zhejiang University	China	2	71
J. Su	The University of Hong Kong	China	3	49
X. Huang	Capital Normal University	China	3	40
S.F. Ahmad	Institute of Business Management	Pakistan	2	32
A. Alam	Indian Institute of Technology Kharagpur	India	2	25

Author	Institution	Country	Number of articles	Number of citations
S.Z. Salas-Pilco	Central China Normal University	China	2	12

According to the institutions the authors are affiliated with, the study examined the rankings of papers and citations. The pertinent facts are shown in Table 4.

**Table 4. Citation Ranking of Country**

Country	Number of articles	Number of citations
China	54	909
USA	21	343
United Kingdom	13	374
India	11	196
Taiwan	11	730
Australia	5	522
Germany	5	503
South Korea	5	156
Canada	4	339
Russia	4	41
Spain	4	94
Turkey	4	33
Greece	3	50
Romania	3	32
Singapore	3	149
Uni Arab Emirates	3	31
Finland	2	35
Georgia	2	13
Iran	2	30
Lebanon	2	14
Oman	2	77
Pakistan	2	32
Serbia	2	43
Sweden	2	30

The table presents data on the number of articles and citations for different countries. China ranks first in terms of the number of articles, with a total of 54 publications. Following China, the United States is in the second position with 21 articles, and the United Kingdom is third with 13 articles. In terms of the number of citations, China maintains its leading position with a significant count of 909 citations. Taiwan secures the second position with 730 citations, while Australia takes the third spot with 522 citations.

**Table 5. Most Cited Articles**

No	Article	Authors	Year	Source	Number of Citations	Citations per year
1	Systematic review of research on artificial intelligence applications in higher education – where are the educators?	O. Zawacki-Richter	2019	International Journal of Educational Technology in Higher Education	424	110.50
2	Exploring the impact of artificial intelligence on teaching and learning in higher education	S.A.D. Popenici	2017	Research and Practice in Technology Enhanced Learning	282	47.00

No	Article	Authors	Year	Source	Number of Citations	Citations per year
3	Evolution and Revolution in Artificial Intelligence in Education (Roll, 2016)	I. Roll	2016	International Journal of Artificial Intelligence in Education	222	31.71
4	Artificial Intelligence in Education: A Review	L. Chen	2020	IEEE Access	204	68.00
5	Robot-proof: Higher education in the age of artificial intelligence	J.E. Aoun	2017	The MIT Press	194	32.33
6	Vision, challenges, roles and research issues of Artificial Intelligence in Education	G.J. Hwang	2020	Computers and Education: Artificial Intelligence	165	55.00
7	Application and theory gaps during the rise of Artificial Intelligence in Education	X. Chen	2020	Computers and Education: Artificial Intelligence	159	53.00
8	Letting Artificial Intelligence in Education out of the Box: Educational Cobots and Smart Classrooms	M.J. Timms	2016	International Journal of Artificial Intelligence in Education	158	22.57
9	Artificial Intelligence trends in education: A narrative overview	M. Chassignol	2018	Procedia Computer Science	147	29.40
10	Introducing artificial intelligence training in medical education	K. Paranjape	2019	JMIR Medical Education	114	28.50
11	An Introduction to Key Technology in Artificial Intelligence and big Data Driven e-Learning and e-Education	P. Gao	2021	Mobile Networks and Applications	96	48.00
12	Artificial intelligence innovation in education: A twenty-year data-driven historical analysis	C. Guan	2020	International Journal of Innovation Studies	89	29.67
13	Artificial Intelligence in Medical Education: Best Practices Using Machine Learning to Assess Surgical Expertise in Virtual Reality Simulation	A. Winkler-Schwartz	2019	Journal of Surgical Education	84	21.00
14	Adoption of artificial intelligence in higher education: a quantitative analysis using structural equation modelling	S. Chatterjee	2020	Education and Information Technologies	82	27.33
15	Artificial intelligence in higher education: A bibliometric study on its impact in the scientific literature	F.J. Hinojo-Lucena	2019	Education Sciences	80	20.00
16	Definition, roles, and potential research issues of the metaverse in education: An artificial intelligence perspective	G.J. Hwang	2022	Computers and Education: Artificial Intelligence	78	78.00



To reveal new trends and tendencies and, most important, further promising directions of the research, it is necessary to construct cluster analysis for the keywords, using the abstracts of papers extracted from the Scopus Database. VOSviewer is proven to be an effective tool for providing keywords visualization which gives the analyst understanding of interconnections between main terms in a field of research (Eck & Waltman, 2020). Using the abstracts of the chosen papers, the network of terms was generated by using a unique clustering technique offered via this program (van Eck & Waltman, 2017). 135 keywords were identified then organized into 6 clusters (Table 2). It can be noted that the words "education", "artificial", "intelligence", "review" have the highest occurrence among the others. For chosen terms, overlay visualization (Figure 3) and density visualization (Figure 4) were performed via VOSviewer. The overlay visualization is chosen as a more valid tool for verification of the recent trends in the academic field, as soon as it allows us to classify the items using timescale. The items are colored differently based on year of publication (average for the cluster). In this case, those terms that appeared recently are more yellow. A color bar shown in the corner has the same explanation; the scores of the items are determined by the time since publication.

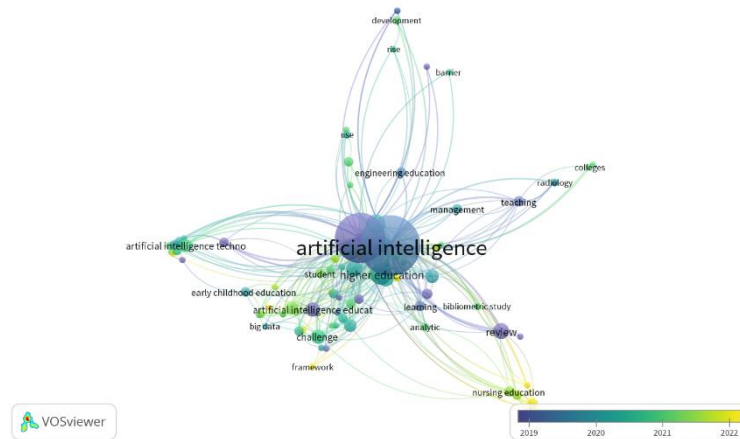


Figure 3. Overlay Visualization of Most Frequent Terms

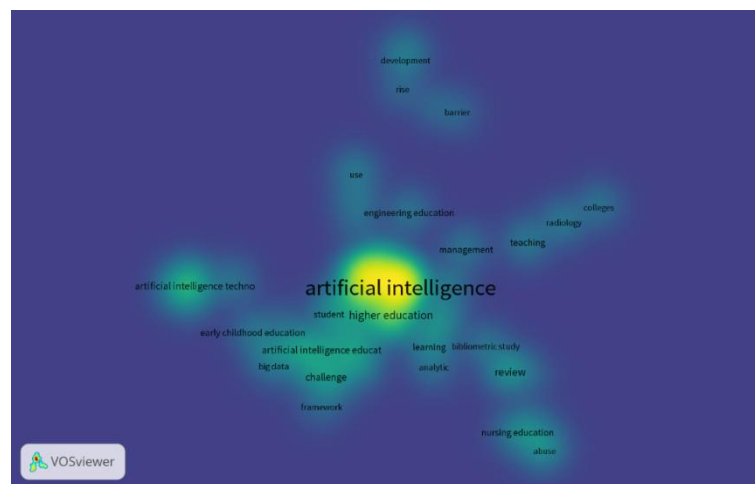


Figure 4. Density Visualization of Most Frequent Terms

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### Discussion

This study focused on analyzing and describing scientific research articles related to AI in education, which were indexed in the Scopus database. The data was analyzed using bibliometric methods and visualized using the VOSviewer software. The findings of the study indicate that there were variations in the number of publications on this topic between the years 2013 and 2023. Based on the research findings, it is evident that the year with the highest number of studies on AI in education is 2021, followed by 2020 and 2022. The initial decline in the number of publications in the early years is likely due to the limited attention and interest in this topic at that time. But the considerable increase in 2019 shows how important and popular AI is becoming in the field of education.

Due to a number of interrelated variables, AI research has been advancing quickly (J. Su, 2022). First, technological developments have significantly accelerated the development of AI (Alam, 2021). Improvements in computing power and data processing, such as GPU capabilities and cloud computing, enable AI to learn and analyze data in more complex and efficient ways. This opens doors for the development of more sophisticated AI algorithms and wider applications.

The availability of a vast amount of data plays a significant role in the advancement of AI research. Across various fields, there is a wealth of data available in diverse formats, including both structured and unstructured data (Kumar & Singh, 2019). This data availability allows researchers to train and test AI models with higher accuracy levels (Kim & MacKinnon, 2018). By having access to quality data, researchers can generate more valuable findings and effective AI solutions (Peres et al., 2020).

The expansion of AI research is also aided by substantial funding and assistance from numerous sources (Albawwat & Frijat, 2021). Many government agencies, technology companies, and other organizations recognize the immense potential of AI and allocate substantial resources to expand research in this field. Research funding, the establishment of AI laboratories, and collaborations between industry and academia are increasingly widespread, providing strong impetus for AI advancements.

The high awareness and demand for innovative AI solutions are also influencing research growth. Various sectors are increasingly realizing the potential of AI in improving efficiency, solving complex problems, and delivering added value to businesses and society (Lin, 2021). This high demand drives researchers to continuously develop new algorithms, techniques, and applications that can meet market needs.

Collaboration and knowledge exchange among AI researchers and practitioners also play a crucial role in research growth. Active AI communities through conferences, scientific journals, online forums, and collaboration platforms enable researchers to share knowledge, learn best practices, and inspire each other. This creates an environment that supports collective AI research growth (H. Su et al., 2022).

The expansion of AI research is also aided by substantial funding and assistance from numerous sources. The potential advantages of AI in various domains serve as an additional driving force behind its development. AI has the capacity to revolutionize our lifestyles, occupations, and social interactions. This potential inspires researchers to create technologies that can genuinely benefit society in areas such as energy, transportation, healthcare, and education. The current growth of AI research can be largely attributed to these factors, which encompass data availability, investment and support, awareness and demand, collaboration, and the anticipated positive impacts (H. Su et al., 2022). They create an environment conducive to innovation and expanding our understanding of the potential applications of AI in various domains.

Based on the data provided, China has emerged as the leading contributor to research on the utilization of AI in education, with a substantial output of 54 articles. Following China, the United States (21 publications) and the United Kingdom (13 publications) rank second and third, respectively. The prominent position of China in this field can be attributed to its strong research capabilities, which encompass renowned academic institutions and research organizations actively involved in the advancement of AI technologies (Wu et al., 2020). China also has active authors who research AI, such

as F. Ouyang, J. Su, X. Huang, and S.Z. Salas-Pilco. Additionally, significant government investment in research and technology development has also propelled AI research in the country. The United States and the United Kingdom also have strengths in AI and education, with renowned universities and research institutions actively contributing to quality research.

In this analysis, *Computers and Education: Artificial Intelligence* is among the publishers that has published the most articles on AI in education. The reputation and widespread acceptance of these journals in the fields of AI and education can be credited with the publisher's success. The scientific community in this discipline pays close attention to the publications published in these journals because they are frequently of a high calibre. The Dutch publication "*Computers and Education: Artificial Intelligence*" covers the fields of social science (education) and computer science (artificial intelligence and computer science applications). Elsevier is the journal's publisher. It has a 17 h-index. This journal belongs to the first quartile.

According to the analysis, G.J. Hwang, X. Chen, and S. O'Connor are some of the most successful researchers in the field of AI in education. Each of them has at least three articles on AI in education under their belts, and they have received numerous citations. S. O'Connor is connected to The University of Manchester, X. Chen to The Education University of Hong Kong, and G.J. Hwang to the National Taiwan University of Science and Technology. These researchers have significantly advanced our knowledge and comprehension of AI in education.

The quality of an article can be assessed by the number of times it is cited by others (Aksnes et al., 2019). With a total of 424 citations, O. Zawacki Richter's study has received the most attention. The *International Journal of Educational Technology in Higher Education* published the findings of this study. The development of publications on AI in higher education through time, the journals in which they are published, the geographical distribution and disciplinary affiliations of the authors, as well as the journals in which they are published, are among the primary findings of the systematic review on AI applications in higher education. The review also provides an overview of the vast array of potential AI applications in higher education to support students, faculty members, and administrators, which were described in four broad areas: profiling and prediction, intelligent tutoring systems, assessment and evaluation, and adaptive systems and personalization. The review also highlights the need for further exploration of ethical and educational approaches in the application of AIEd in higher education (Zawacki-Richter, 2019).

Based on co-occurrence analysis, some of the most commonly used keywords in research on AI in education include AI technology, early childhood education, AI education, big data, engineering education, AI application, AI learning, assessment, chatgpt, higher education, language education, medical education, ophthalmology, personalized education, and virtual reality. The keywords identified in the analysis are indicative of the diverse areas of focus when it comes to the implementation and utilization of AI in the educational context. One aspect that these keywords highlight is the application of AI technology in learning (Ali, 2020). This includes using AI algorithms and systems to speed up and improve the learning process while giving students individualized and flexible learning opportunities. AI can help in the distribution of content, adaptive testing, intelligent tutoring systems, and other cutting-edge methods to maximize learning outcomes.

Another important aspect reflected in the keywords is the role of AI in evaluation and feedback (Crompton, 2022). AI can be used to automate and streamline the evaluation process, giving students quick feedback on their performance and development. This can improve the effectiveness of educational interventions overall, help identify areas for improvement, and customise learning experiences to meet individual requirements. Additionally, AI-based analytics can offer insightful data on patterns and trends in student performance, empowering teachers to make data-driven decisions and interventions.

The keywords also shed light on the role of humans in the use of AI. While AI technology can offer numerous benefits, it is essential to understand and explore the dynamic interaction between humans and AI systems in the educational context (Shin, 2020). This entails looking at how human teachers and AI tools work together, addressing ethical issues, and making sure that technology is applied in a way that enhances and supports human knowledge and pedagogical approaches. To

successfully integrate AI in education and to take advantage of its potential while preserving the critical human touch in the learning process, it is essential to have a thorough understanding of how humans and AI interact.

Lastly, the keywords highlight the importance of systematic reviews related to the use of AI in education. Systematic reviews provide a comprehensive analysis and synthesis of existing research on a specific topic. They offer valuable insights into the effectiveness, limitations, and best practices of AI implementation in education. By examining and synthesizing a wide range of studies, systematic reviews help researchers, policymakers, and educators make informed decisions and identify gaps for future research. These reviews play a crucial role in advancing the knowledge and understanding of AI's impact on education and guiding evidence-based practices in the field,

### Conclusion

Based on the analysis of scientific research articles indexed in the Scopus database, it is evident that the trend of research on AI in education has experienced significant growth and evolution over the past decade. The data reveals fluctuations in the number of publications between 2013 and 2023, with a noticeable surge in studies observed particularly from 2019 onwards. This increasing interest reflects the recognition of AI's transformative potential in educational settings, underpinned by technological advancements, data availability, funding support, and heightened demand for innovative solutions.

The trajectory of AI research in education indicates promising prospects for future exploration and development. With ongoing technological advancements and the growing availability of data, AI research is likely to continue expanding across various educational domains. Moreover, the collaboration and knowledge exchange among researchers, coupled with substantial funding support, are expected to further accelerate the pace of AI research in education.

Additionally, the identification of prominent contributors, such as China, the United States, and the United Kingdom, underscores the global significance and interdisciplinary nature of AI research in education. These findings suggest a continued interest and investment in advancing AI technologies and applications to address diverse educational challenges and enhance learning experiences.

Moving forward, the integration of AI into educational practices requires a nuanced understanding of its potential benefits and implications. Ethical considerations, human-AI interaction dynamics, and the need for systematic reviews underscore the importance of comprehensive and interdisciplinary research approaches in shaping the future direction of AI in education. By addressing these critical areas and leveraging AI's capabilities effectively, researchers can contribute to the creation of innovative and inclusive educational environments that empower learners and educators alike.

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