Visualization of Hotspots and Trends in AI in Education

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Abstract. This study aims to reveal the application trends of artificial intelligence (AI) in the field of education. Using the Web of Science database, 133 relevant papers were selected, and CiteSpace was used to perform co-occurrence analysis of authors, institutions, and keywords. The analysis results show that research in this field has grown rapidly since 2017, with a significant acceleration after 2021. Collaboration analysis among authors and institutions highlights the key role of major institutions such as the University of London. Keyword analysis indicates that areas such as "generative AI," "learning analytics," "intelligent tutoring systems," and "adaptive assessment" are gaining attention, reflecting the potential of AI in personalized learning.

Keywords: AI in education, CiteSpace, Visualization

1 Introduction

The rapid development of Artificial Intelligence (AI) is swiftly transforming the way we conduct our daily activities[1]. In the field of education, AI has brought significant changes to teaching implementation, learning strategies, and quality assessment[2]. Emerging learning analytics models and AI-driven educational systems offer potential solutions for personalized learning[3]. Maier[4] and Cavalcanti[5] developed intelligent tutoring systems capable of providing automatic feedback on student performance. Williamson[6] utilized learning analytics dashboards to track student progress. Carter & Egliston[7] introduced gamified virtual reality into educational systems, enhancing interactivity and personalization. Educational data analytics is another significant application area of AI in education. By mining and analyzing vast amounts of educational data, AI can provide scientific decision-making support for educational administrators and precise teaching suggestions for teachers.

However, some scholars hold a negative view of AI applications in education. Viberg[8]express grave concerns about potential student privacy violations and educational data leaks caused by AI-driven educational systems (LA/AIED). Additionally, the lack of student and teacher involvement in the design and development of AIED

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systems may lead to insufficient trust in the technology due to a lack of understanding by users[9-10].

To conduct an objective analysis of the hotspots and trends of AI applications in education, this study takes recent academic literature on AI in education as research material and uses the CiteSpace visualization analysis tool to systematically review the development history, research hotspots, and application status of AI in education.

2 Research Methods

2.1 Data Sources

To ensure the comprehensiveness and reliability of the analysis, this study obtained relevant data from the Web of Science database. By utilizing the advanced search function, the search terms were set as "AI in Education," "Artificial Intelligence in Education," and "Machine Learning in Education," aiming to cover multi-dimensional applications of AI in education. The time span for the search was set from 2010 to 2024, a total of 15 years, to ensure the historical continuity and timeliness of the data. The specific execution time for the search was October 22, 2024. After data screening and sorting, a total of 133 relevant papers were obtained, and the Full Record and Cited References were exported in the form of Plain Text File for subsequent analysis.

2.2 Data Analysis Tool

CiteSpace is a visualization analysis tool based on the Java language environment, designed to help users delve into scientific literature and reveal underlying patterns and trends. The tool treats keywords in scientific literature as nodes and connects these nodes through citation relationships, forming a visualized graphic network that showcases the relationships between different disciplines. The core analysis method of CiteSpace relies on the generated graphics, through systematic analysis and interpretation of the graphics, to identify patterns, trends, and cross-disciplinary connections in the literature. CiteSpace supports knowledge maps such as author co-occurrence analysis, institution co-occurrence analysis, and keyword co-occurrence analysis, as well as clustering maps and burst term analysis, to uncover academic research hotspots and developmental trends within specific time periods.

3 Visualization of Hotspots and Trends

3.1 Visualization of Paper Publication Volume

According to the Web of Science database, a total of 133 papers were retrieved with the subject “AI in Education,” “Artificial Intelligence in Education,” or “Machine Learning in Education.” As shown in Figure 1, the publication volume in this research field has exhibited a significant growth trend since 2017, particularly accelerating after

2021. The number of papers published reached 20 and 29 in 2022 and 2023, respectively, indicating a strong interest from the academic community in the research on "Artificial Intelligence in Education." Notably, the publication volume in 2024 has reached 60 papers, further validating the rapid development of this field. Additionally, citation counts have shown a significant increase since 2019, especially in 2024, when the citation count reached 1,008, indicating that the academic impact of this field is also continuously growing, holding substantial potential academic value.

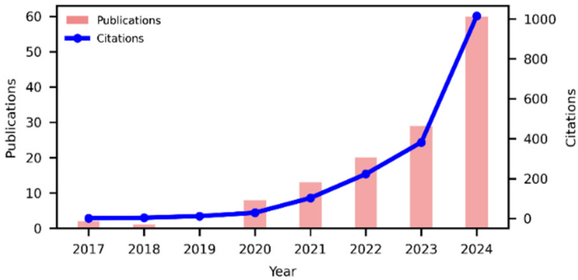

Fig. 1. Visualization of paper publication volume

3.2 Visualization of the Author Collaboration Network

In the author co-occurrence analysis, the density of connections can be used to analyze the collaboration strength among core authors in the field. During co-occurrence analysis, CiteSpace represents the collaborative relationships among multiple authors as a graphical network structure. In the author collaboration network diagram, each author is represented as a node, and the collaborative relationships between authors are indicated by edges, with the weight of the edges signifying the frequency of collaboration or other metrics. By analyzing these network diagrams, one can reveal collaboration patterns among authors, identify key authors, and determine collaborative research directions within the field. As shown in Figure 2, there are 149 co-occurring authors (partially displayed), with 190 connections, resulting in a network density of 0.0172. We can see 11 authors, including Abbosh Amin, Bai Jinshuai, and Alzubaldi Laith, who mainly research the safety, reliability, and trustworthiness of AI systems, forming relatively stable collaborative relationships, while collaborations among other authors are comparatively loose.

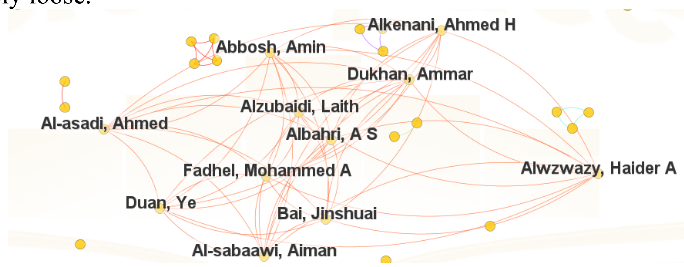

Fig. 2. Visualization of the Author Collaboration Network

3.3 Visualization of Research Institutions

As Figure 3 shown that research institutions exhibit a certain degree of diversity and complexity in this field. In 2024, the University of London ranks first with a quantity of 5 and a centrality value of 0.01, indicating its significance in this field. Meanwhile, Universidad de Valladolid, Queen Mary University London, University College London, and UCL Institute of Education all follow closely with a quantity of 3 and a centrality value of 0.01, showing a relatively high level of involvement in this field.

The Education University of Hong Kong, University of pittsburgh, and the Utrecht University all show a quantity of 2 in 2024, but these institutions have lower centrality values, indicating relatively small influence in this field. Well-known universities such as Harvard University, Stanford University, and the Swiss Federal Institute of Technology also show lower centrality values, reflecting the need for enhanced academic influence. In this new field, research institutions are relatively dispersed, and no central institution has emerged.

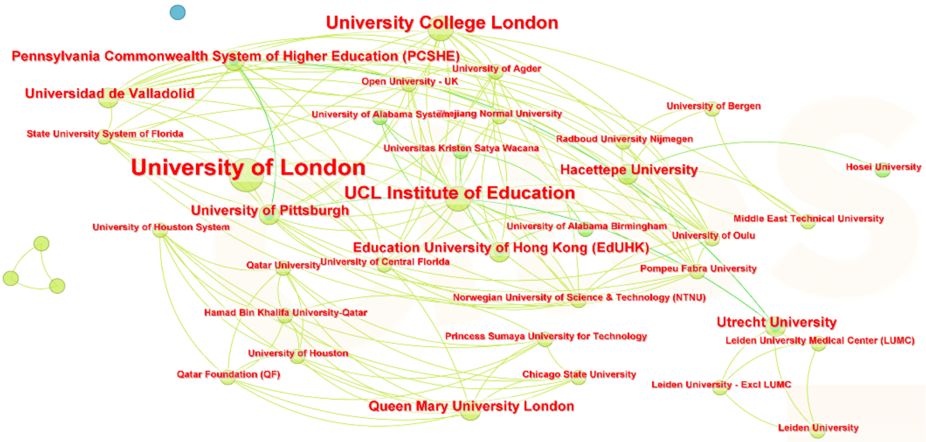

Fig. 3. Visualization of Research Institutions

3.4 Keyword Co-occurrence Visualization

Through keyword co-occurrence analysis, we can observe the trends in research areas related to educational technology and machine learning over the past few years. As shown in Figure 4, "machine learning" and "deep learning" are high-frequency keywords in 2021 and 2024, indicating that the applications of these technologies in the education field are receiving increasing attention. Particularly in 2021, "machine learning" had a co-occurrence frequency of 12 times, showing its significant position in academic research. Keywords such as "students" and "educational technology" also appear frequently, reaching a peak in 2018 and 2017 respectively, reflecting students as the primary audience and the historical development of educational technology. Additionally, "generative AI" and "large language models" have gradually gained attention as emerging fields in 2023 and 2024, especially in research related to "performance" and "adaptive learning."

In terms of specific applications, "learning analytics" and "adaptive learning" were important research directions in 2020 and 2021, while "intelligent tutoring systems" and "automated assessment" continued to be emphasized in 2022 and 2024, particularly in the combination of "adaptive assessment (aa)" and "intelligent tutoring systems (its)", showing the potential value of technology in educational assessment. It is worth noting that although the co-occurrence frequency of "adoption" and "user acceptance" is low, their frequency of appearance increased in 2024, indicating that researchers are beginning to pay more attention to issues of technology adoption and user acceptance. Similarly, the appearance of "challenges" in 2023 shows researchers' awareness of the issues faced when implementing new technology.

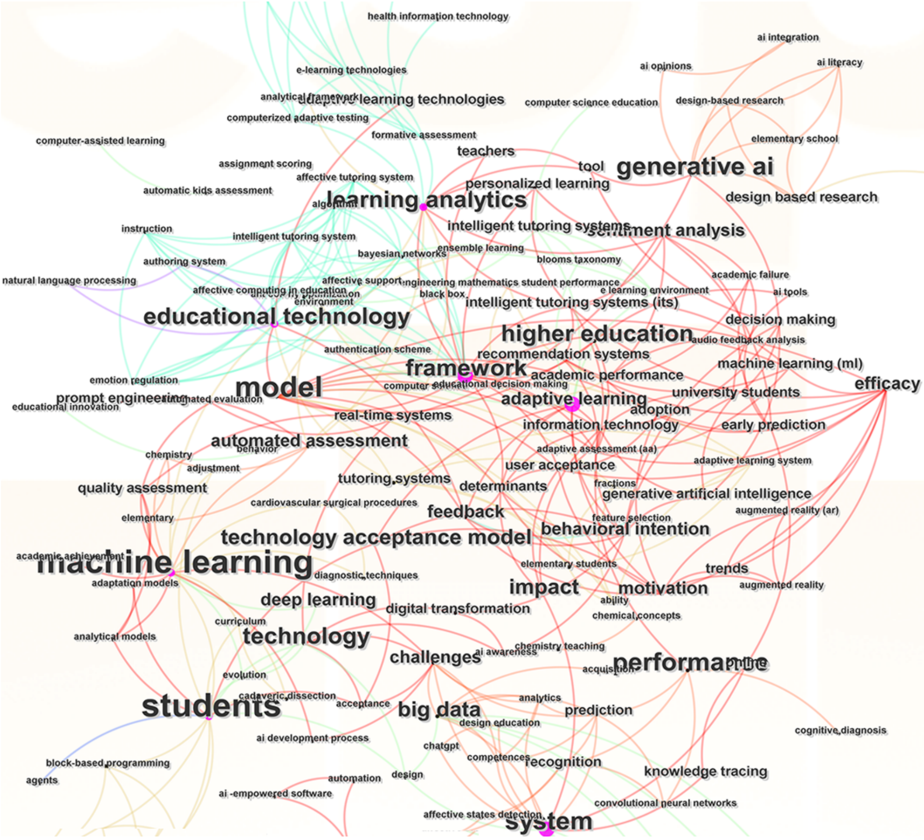

Fig. 4. Keyword Co-occurrence Visualization

3.5 Keyword Burst Visualization

The emerging landscape of artificial intelligence (AI) in education is significantly shaped by key developments evidenced in recent years. As shown in Figure 5, a notable keyword is "generative AI," which has gained a strength index of 1.31 in 2023, reflecting its transformative potential in creating personalized educational content and experiences. In conjunction with generative AI, "intelligent tutoring systems," with a strength of 1.13 in 2021, represent a vital aspect of AI's integration into education. Furthermore, the importance of "big data" in education, evidenced by a strength of 0.87 in 2021, enables educators and institutions to analyze vast amounts of information regarding student performance and learning behaviors. Complementing this approach is "learning analytics," which peaked at 0.71 in 2020. This field empowers educators to monitor real-time student progress, facilitating informed decision-making to enhance both teaching and learning processes. Moreover, the keywords from 2020—including "e-learning technologies," "affective computing in education," and "formative assessment," each showing a strength of 0.62—illustrate a comprehensive strategy that integrates AI into various aspects of the educational experience.

Keywords	Year	Strength	Begin	End	2017 - 2024
generative ai	2023	**1.31**	2023	2024	
intelligent tutoring systems	2021	**1.13**	2021	2021	
big data	2021	**0.87**	2023	2024	
learning analytics	2020	**0.71**	2022	2022	
leaving risk	2017	**0.67**	2017	2017	
natural language processing	2017	**0.67**	2017	2017	
active video-viewing time	2017	**0.67**	2017	2017	
e-learning technologies	2020	**0.62**	2020	2020	
affective computing in education	2020	**0.62**	2020	2020	
formative assessment	2020	**0.62**	2020	2020	
instructional tools	2020	**0.62**	2020	2020	
knowledge transfer	2020	**0.62**	2020	2020	
computerized adaptive testing	2020	**0.62**	2020	2020	
emotion regulation	2020	**0.62**	2020	2020	
interactive narrative generation	2020	**0.62**	2020	2020	
automated assessment	2022	**0.58**	2022	2024	
computer-assisted learning	2021	**0.57**	2021	2021	
adaptive skills	2021	**0.57**	2021	2021	
automated essay scoring	2021	**0.57**	2021	2021	
education advisory system	2021	**0.57**	2021	2021	
adaptive learning system	2022	**0.56**	2022	2022	

Fig. 5. Keyword Burst Visualization

4 Conclusion and Discussion

This study highlights the rapid advancement of AI in education, with findings demonstrating notable growth in research activity since 2017 and accelerating after 2021. Despite providing valuable insights, this study faces certain limitations. First, the dataset is restricted to publications within the Web of Science database, which, while extensive, may omit relevant work published in other databases or non-English sources, potentially limiting the scope of the analysis. Additionally, the co-occurrence analysis, while effective for visualizing collaboration and topic trends, may not fully capture the depth of these collaborations or the nuances within individual research contributions. The findings mainly reflect broad trends and influential terms but do not delve deeply into specific AI methodologies or applications.

Future research could expand the scope by including a wider range of databases and by exploring the application of AI methodologies in varied educational contexts and age groups. Moreover, addressing the challenges of user acceptance and practical adoption will be crucial in ensuring AI's effective integration into education. By exploring the impact of AI across different learner demographics and environments, future studies can contribute to a more robust and practical application of AI-driven education technologies.

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