

Visualization and analysis of the current status and frontiers of combining education and artificial intelligence

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Abstract: Amid the wave of educational transformation in the intelligent era, the deep integration of artificial intelligence (AI) and education has become a key driver of educational modernization. Based on 1,000 articles retrieved from the Web of Science Core Collection, this study employs CiteSpace for visualization analysis to systematically examine the research trajectory and evolution of the field of Artificial Intelligence in Education (AIED). The findings reveal a three-stage evolution pattern, from “technological empowerment” to “scenario innovation” and ultimately to “mechanism reconstruction.” China, leveraging policy support and practical advantages, has emerged as a global research hub, forming an academic network characterized by teacher-training institutions as the main body and international collaboration as the bridge. Keyword clustering identifies 17 research communities, including technology acceptance models, adaptive learning, and the metaverse, while emerging topics such as large language models and cognitive load theory reflect a paradigm shift in the field. Future research should focus on multimodal interaction, educational equity, and ethics, thereby fostering the construction of an intelligent education ecosystem with humanistic care.

1. Introduction

In today's digital age, information technology is growing exponentially. Artificial Intelligence (AI), as one of its most transformative forces, is profoundly reshaping how people live and work[1]. Notably, AI is also increasingly permeating the field of education (AIED)[2]. Quality education, as one of the United Nations' 17 Sustainable Development Goals, is dedicated to ensuring inclusive, equitable, and quality education, enabling lifelong learning opportunities for all[3]. Leveraging core algorithms like deep learning and machine learning, AI constructs vast and efficient data processing systems. Its formidable data processing capabilities enable deep mining and analysis of massive, multi-source, heterogeneous data generated during education—such as student learning behavior data and teaching resource usage data—providing robust support for personalized teaching

decisions. Its personalized interaction capabilities break through the limitations of traditional “one-size-fits-all” education[4]. Through applications like intelligent tutoring systems and virtual learning companions[5], AIED achieves precise alignment between educational services and individual student needs, fundamentally reshaping traditional educational models[6]. Furthermore, in building an intelligent education ecosystem, AIED plays an irreplaceable core role in key scenarios such as virtual classrooms, smart campuses, and intelligent tutoring systems[7].

Amidst the rapid technological evolution, computer science continues to advance, and emerging AI will further shape education's future, presenting unprecedented opportunities and challenges[8]. Academic circles have conducted extensive research and exploration on the theme of “Education and Artificial Intelligence.” Building upon this foundation, it is necessary to organize and statistically analyze previous scholarly findings. This paper employs CiteSpace to conduct a visualization analysis of articles related to the integration of education and artificial intelligence. On one hand, this helps scholars understand and grasp the current state of research in this field, comprehend the connections and evolution between the two themes of “education” and “artificial intelligence,” and quickly locate core literature in this domain. On the other hand, the visualization clearly presents the relevant clusters and collaborative networks between the two major themes, which is also of great significance for scholars to discover research gaps and facilitate interdisciplinary research.

2. Data sources and methods

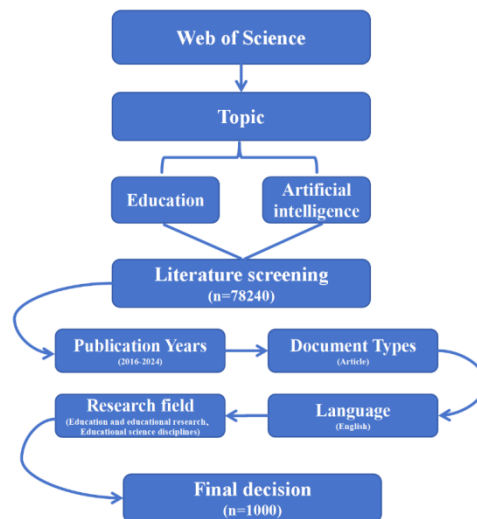


Fig 1.Selection process flowchart

In order to examine the development trends, research institutions and personnel, keyword clustering, and the cutting-edge status in the field of Artificial Intelligence in Education (AIED), we utilized the Web of Science (WOS) for literature retrieval. The core dataset from WOS was selected, and a search was conducted using the keywords “education” and “artificial intelligence.” Initially, we identified 78,240 papers. To enhance the accuracy and relevance of our findings, we imposed restrictions on various search parameters including “publication year,” “article type,” “Web of Science category,” and “language.” Firstly, it is important to note that since this article's retrieval date is May 2025, the literature retrieved from that year does not represent the total number of publications for 2025. The time frame selected for our analysis spans from 2016 to 2024. We specifically focused on articles classified as “Article.” The categories within Web of Science were determined as: Education and Educational Research along with disciplines related to educational

science. Additionally, only English-language articles indexed by SSCI were considered in our final selection process. Ultimately, this rigorous filtering resulted in a total of 1,000 documents being retained for further analysis. The process of selecting articles is shown in Fig 1.

Professor Chaomei Chen of the United States created CiteSpace, an information visualization program, for the purpose of analyzing scientific publications[9]. CiteSpace is mostly used in this thesis to investigate the national distribution, cluster analysis of keywords, and the temporal evolution of the number of literatures.

3. Current state of research in education and artificial intelligence

3.1 Number of documents and number of countries

As shown in Figure 2, the development of the “Education and Artificial Intelligence” field can be divided into two phases: a slow growth period (2016 – 2018) and a rapid development period (2019 – 2024). During the early phase, the number of publications consistently remained in the single digits, reflecting immature technology, nascent applications, and slow research progress. Starting in 2019, publication volume surged rapidly, reaching 215 papers in 2023 and 533 papers in 2024. Key drivers include: breakthroughs in deep learning and natural language processing enabling applications like intelligent tutoring and personalized recommendations; and intensifying educational reforms and demand for high-quality education, accelerated by policy support, driving AI-education integration. This dual momentum of technological advancement and educational demand has fueled research prosperity.

By country distribution, China leads with 409 publications, benefiting from its vast educational system, diverse application scenarios, sustained research investment, and policy guidance. The United States follows with 174 publications, leveraging its robust AI foundation and innovative educational traditions to achieve significant results. Countries like Australia (83), the United Kingdom (72), and South Korea (50) also maintain active research, focusing on optimizing teaching models and enhancing learning outcomes. Singapore (27 papers) and New Zealand (17 papers), though contributing fewer papers, are actively pursuing advancements. The overall trend indicates sustained global research momentum in this field, characterized by both competition and collaboration: nations intensify R&D investments to secure influence, while transnational partnerships foster resource sharing and joint breakthroughs. This demonstrates that education and AI research are undergoing rapid evolution alongside international cooperation, with promising future prospects.

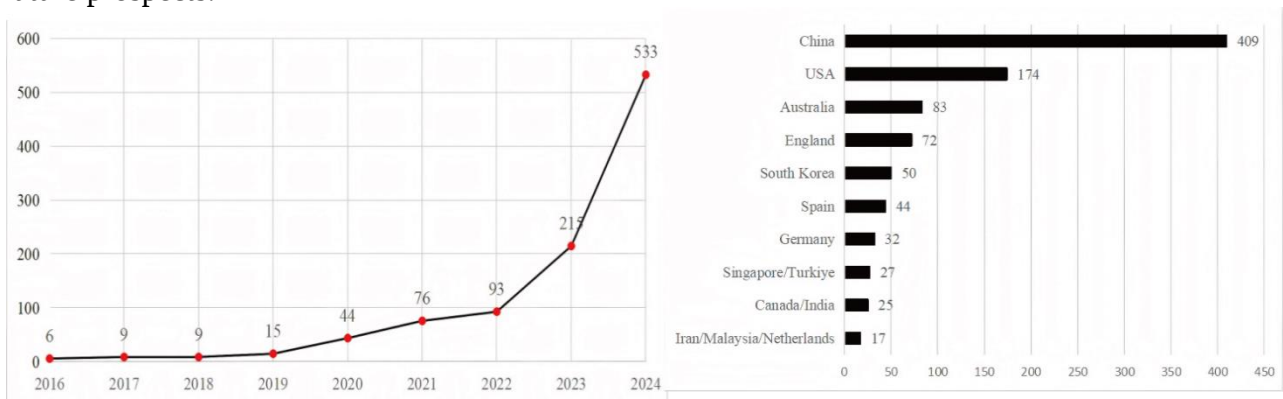


Fig 2. Publication trends and country distribution in education and artificial intelligence research

3.2 Authors and institutions

The collaboration network structure in Figure 3 reveals that scholars such as “Chiu, Thomas K F,” “Yang, Yubin,” and “Chu, Samuel Kai Wah” occupy central positions, maintaining close collaborations with numerous researchers and serving as vital hubs connecting diverse teams. Through extensive collaborative networks, they integrate diverse resources, accelerate the dissemination of cutting-edge concepts and technologies, foster multi-perspective exchanges, and propel the field toward deeper and more comprehensive development, playing a leading role in the flourishing of education and AI research.

At the institutional level, universities such as Central China Normal University, Education University of Hong Kong (EdUHK), and the University of Hong Kong have formed close cooperative relationships, with teacher training institutions being particularly prominent. Leveraging their deep foundations in educational theory and teaching practice, these institutions actively explore the deep integration of AI and education, driving educational innovation and transformation. Meanwhile, transnational collaboration is a prominent feature, with Chinese universities maintaining close ties with institutions such as the University of California system and the University of London. Through resource integration and complementary strengths, international cooperation not only helps overcome challenges in the convergence of education and AI but also injects new momentum into global educational development.



Fig 3. Author and institutional collaboration network in the field of education and artificial intelligence integration

3.3 Keyword clustering

Keywords effectively reflect research hotspots. This study employed CiteSpace for keyword clustering analysis, revealing 17 distinct categories spanning technology, educational contexts, and learning theories. Different colors represent distinct themes, node sizes indicate frequency of occurrence, and connecting lines reflect co-occurrence relationships.

As shown in Figure 4, the “Technology Acceptance Model” focuses on educational stakeholders’ willingness to adopt and utilize AI; “language learning” highlights its applications in speech evaluation and personalized learning pathways; “artificial intelligence” serves as the core technology spanning all research directions; while “higher education” emphasizes its practical implementation in curriculum design and talent cultivation. Keywords like “artificial intelligence” appear most frequently and are closely linked to “language learning” and “higher education,” indicating deep integration between technology and educational contexts. These interconnected themes mutually reinforce each other, driving diversified research development. This research network provides robust support for exploring how AI can revolutionize educational models and enhance learning outcomes, accelerating the intelligent transformation of education.

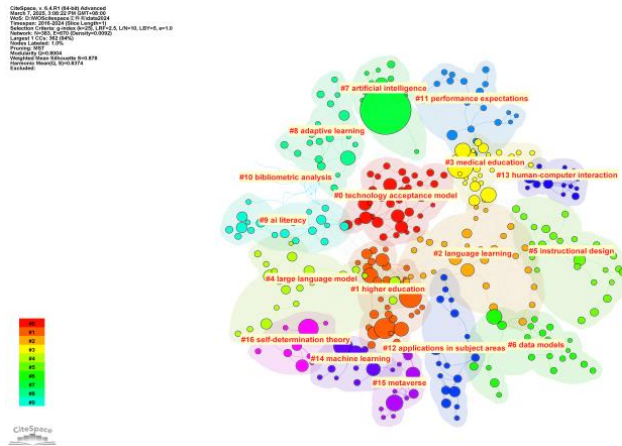


Fig 4. Keyword clustering of research combining education and AI

3.4 Frontier analysis of the integration of education and artificial intelligence

In academic research, “emergence” reflects the rapid growth of keywords during specific periods, thereby aiding in the identification of research frontiers. By leveraging CiteSpace's emergence analysis feature, core keywords in the field of education and artificial intelligence can be extracted and tracked, revealing the evolutionary trajectory of research hotspots[10].

As shown in Table 1, the development of this field follows a clear logic of “technology introduction—scenario application—mechanism exploration.” In the early phase (2017 – 2020), “big data”(5.78) and “machine learning”(5.77) emerged as high-frequency keywords, with research focusing on introducing big data and machine learning into education to lay the foundation for intelligent analysis and data mining. During the mid-phase (2020 – 2022), keywords like “learning analytics,” “academic performance,” and “children” emerged, shifting research attention toward learning analytics, academic outcomes, and educational practices for specific groups. This marked a transition from technology introduction to concrete application scenarios. In the later phase (2022 – 2024), “artificial intelligence in education”(2.87) and “cognitive load” (2.77) became central themes. Research concentrated on the systematic application of AI in education and cognitive load issues, reflecting a return to “human-centered values” in educational research.

Table 1. Keywords appearing in the research on the combination of education and AI

Keywords	Intensity	Starting time	Ending time
big data	5.78	2017	2021
system	2.13	2018	2019
machine learning	5.77	2020	2021
learning analytics	2.91	2020	2021
academic performance	2.21	2020	2022
children	2.13	2020	2022
science	2.39	2021	2022
mobile learning	2.13	2021	2022
artificial intelligence in education	2.87	2022	2024
cognitive load	2.77	2022	2024

Overall, research in this field has evolved from technology-driven approaches to scenario expansion and then to mechanism exploration. This trajectory aligns with the logic of technological

advancement while emphasizing educational research's focus on learners. Moving forward, we should deepen our reflection on the essence of education within technological applications, balancing innovation with established principles to advance human-machine collaboration and the development of intelligent, human-centered educational models.

4. Conclusion

This study employs visual analysis to map the knowledge landscape of educational artificial intelligence, revealing its interdisciplinary nature and dynamic evolution patterns. Key findings include:

(1) The convergence of education and artificial intelligence has emerged as a research hotspot. China leads globally in publication volume, driving development in this field through its extensive education system, policy support, and research investment.

(2) Scholars including Chiu, Thomas K F, Yang, Yuqin, and Chu, Samuel Kai Wah occupy central positions, driving cross-team collaboration. Teacher training institutions such as Central China Normal University and The Education University of Hong Kong demonstrate outstanding performance, with international cooperation further deepening research.

(3) Keyword clustering identifies 17 research communities—including Technology Acceptance Models, Adaptive Learning, and the Metaverse—characterized by strong interconnections.

(4) Research frontiers have shifted from “technology-tool orientation” to “scenario application” and then to “educational ontology orientation”: early focus on big data and intelligent tutoring expanded mid-term to language and medical education, while recent work delves into cognitive load and self-determination theory, reflecting education research's return to the “essence of nurturing talent.”

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References

- [1] Bharti, T., Ojha, S. C., & Tiwari, A. K. (2022). *Interplay of Workplace Sustainability, Sustainable Work Performance, Optimism, and Resilience: The Moderating Role of Green Creativity in Luxury Hotels*. *Sustainability*, 14(22).
- [2] Chen, X., Xie, H., Zou, D., & Hwang, G.-J. (2020). *Application and theory gaps during the rise of artificial intelligence in education*. *Computers and Education: Artificial Intelligence*, 1, 100002.
- [3] Agbedahin, A. V. (2019). *Sustainable development, Education for Sustainable Development, and the 2030 Agenda for Sustainable Development: Emergence, efficacy, eminence, and future*. *Sustainable development*, 27(4), 669-680.
- [4] Akgun, S., & Greenhow, C. (2022). *Artificial intelligence in education: Addressing ethical challenges in K-12 settings*. *AI and Ethics*, 2(3), 431-440.
- [5] Chiu, T. K., Xia, Q., Zhou, X., Chai, C. S., & Cheng, M. (2023). *Systematic literature review on opportunities, challenges, and future research recommendations of artificial intelligence in education*. *Computers and Education: Artificial Intelligence*, 4, 100118.
- [6] Su, J., Ng, D. T. K., & Chu, S. K. W. (2023). *Artificial intelligence (AI) literacy in early childhood education: The challenges and opportunities*. *Computers and Education: Artificial Intelligence*, 4, 100124.
- [7] Ahmad, S. F., Alam, M. M., Rahmat, M. K., Mubarik, M. S., & Hyder, S. I. (2022). *Academic and administrative role of artificial intelligence in education*. *Sustainability*, 14(3), 1101.
- [8] Zafari, M., Bazargani, J. S., Sadeghi-Niaraki, A., & Choi, S.-M. (2022). *Artificial intelligence applications in K-12 education: A systematic literature review*. *IEEE Access*, 10, 61905-61921.
- [9] Zhang, F., Wang, X., & Zhang, X. (2025). *Applications of deep learning method of artificial intelligence in*

education. *Education and Information Technologies*, 30(2), 1563-1587.

[10] Jing, X., Zhu, R., Lin, J., Yu, B., & Lu, M. (2022). Education sustainability for intelligent manufacturing in the context of the new generation of artificial intelligence. *Sustainability*, 14(21), 14148.