Original article

Research on the application of ChatGPT in education—visual analysis based on CiteSpace

Zhefeng An[ID]*, Jiajun Ma

Institute of Higher Education, Beijing University of Technology, Beijing 100124, P. R. China

Abstract:
The impact of generative artificial intelligence (generative AI) technology, exemplified by ChatGPT, on education is substantial. CiteSpace visualization software is used in this study to analyze Chinese and English core journal literature on ChatGPT in education from 2013 to 2023. The comparison is grounded in factors such as the volume of publications, distribution across disciplines, core authors and institutions, research hotspots, and trends in research. The literature was retrieved from the databases of the China National Knowledge Infrastructure and Web of Science. The analysis unveils a limited number of studies yet indicates an overall increasing trend. Collaboration between core authors and institutions should be strengthened. Research hotspots, areas, and trends differ in the Chinese and English literature. In the future, researchers should concentrate on innovating research methods, diversifying research perspectives and fields, developing specialized models, and improving relevant laws and guidelines.

1. Introduction

On November 30, 2022, the ChatGPT, developed by OpenAI based in the US, was publicly unveiled. This model represents a significant step forward in generative AI, setting it apart from previous analytical AI technologies (Chen, 2023). It is built on the Transformer architecture, which employs reinforcement learning techniques to train on many manually annotated text data. This allows the model to gain a deep understanding of textual input and generate coherent text that is relevant and different from the training data (Yang et al., 2023).

Currently, research on the application of ChatGPT in education is fragmented. There is a lack of comprehensive quantitative analyses in this field, making it challenging to determine progress, hotspots, and future trends. CiteSpace is a Java-based information visualization software that uses co-citation analysis theory and the pathfinder algorithm to quantify literature in specific domains. The software aims to reveal essential paths and key knowledge points in the

development of academic disciplines. The visual map presentation thoroughly examines the possible dynamic mechanisms of disciplinary growth and investigates the latest trends in disciplinary development (Chen et al., 2015).

This study selects the time frame between 2013 and 2023 and employs CiteSpace visualization software to analyze core journal literature related to the research of ChatGPT in education from China National Knowledge Infrastructure (CNKI) and Web of Science (WOS). The aim is to illuminate hotspots and development trends in the recent research of ChatGPT in education and explore the future direction of generative AI in education.

2. Data source and research method

2.1 Data source

Given that ChatGPT was released in 2022, we expanded our search terms to include "Generative Artificial Intelligence" to reflect the changing trends in AI-related research in education. For comprehensive and precise literature acquisition,

this paper selects the China National Knowledge Infrastructure database as the source for Chinese data. Using the "advanced search" function, the search criteria are set as follows: Topic = "Generative Artificial Intelligence" OR "ChatGPT" AND "Education", source category = "Peking University Core" OR "CSSCI", search condition = "Exact", literature category = "Academic journals", time range = "2013 to 2023", with the Synonym expansion option checked, resulting in retrieval of 214 papers. The search results are exported in RefWorks format and subsequently transformed, resulting in 214 accessible documents.

English data is sourced from the SCI-Expanded and SSCI databases within the Web of Science Core Collection. The search criteria are defined as (TS = (ChatGPT) OR TS = (generative artificial intelligence)) AND TS = (education) using the "advanced search" function. The specified parameters included Index Date = 2013 to 2023, Document Types = Article, and Language = English, resulting in the retrieval of 144 papers. The results are exported in plain text file format and subsequently transformed. Each literature entry encompasses information such as title, author, institution, abstract, keywords, publishing time, publishing journal, and cited references.

2.2 Research method

Using the bibliometric analysis tool CiteSpace, this study employs bibliometrics, data visualization, and statistical analysis methods. CiteSpace 6.1.R6 is utilized, with the time frame set from January 2013 to December 2023 and a time slice configured to 1 year. Coupled with visualization maps and background data, this study conducts annual publication statistics, discipline distribution statistics, core author analysis, high-frequency institution analysis, country analysis, high-frequency keyword analysis, keyword clustering analysis, and keyword emergence analysis on Chinese and English literature data, in order to gain a comprehensive understanding of the research and development trends in the application of ChatGPT in education.

3. Statistics and analysis of research basis data

3.1 Statistical analysis of annual publication

3.1.1 Statistics on the number of annual publications of Chinese literatures

Fig. 1 is a frequency chart illustrating the annual publication volume derived from the analysis of Chinese core journal papers retrieved from the China National Knowledge Infrastructure. It is evident from the figure that research on the application of generative AI in education emerged in 2018, while the number of relevant studies was notably limited until 2022, amounting to merely six core journal papers. This suggests that Chinese scholars have shown minimal attention to the research in this area. However, in 2023, there was a remarkable surge in core journal papers within this field. By the final search conducted on December 1 for this paper, the number of core journal papers in this field in 2023 reached 208. This signifies the rapid emergence of research on

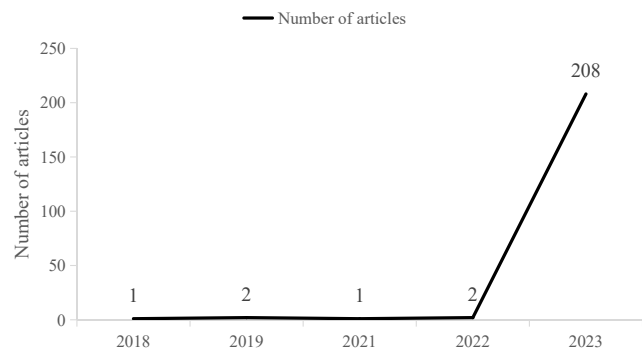generative AI and ChatGPT applications in education, which is notable among Chinese scholars.

Fig. 1. Change in the number of annual published Chinese articles.

3.1.2 Statistics on the number of annual publications of English literature

Fig. 2 presents a frequency chart illustrating the annual publication volume derived from the analysis of English core journal papers retrieved from the Web of Science. Similar to the trend in Chinese research, the number of English studies on the application of generative AI and ChatGPT in education was scarce before 2023, indicating a comparatively low level of research attention in this field. However, with the emergence of ChatGPT, core journal papers in this field experienced explosive growth in 2023, resembling the trend observed in the Chinese situation. As of the final search conducted on December 1 for this paper, the number of core journal papers in this field for 2023 reached 133, signifying the rapid emergence of research on generative AI and ChatGPT application in education as a research hotspot for English scholars.
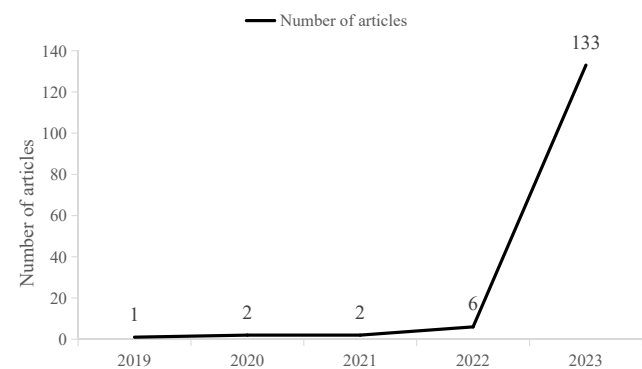

Fig. 2. Change in the number of annual published English articles.

In summary, the launch of ChatGPT in November 2022 has garnered significant academic attention. In merely one year, scholars have conducted numerous studies indicating that the use of ChatGPT in education has become a prominent research focus in academia. A strong correlation exists between the trend of literature issuance and the development of generative AI. It is foreseeable that the quantity of studies in this field

will continue to experience explosive growth with the rapid, iterative updating of generative AI.

3.2 Discipline distribution

3.2.1 Discipline distribution of Chinese literature

Fig. 3 illustrates the distribution of the top 10 disciplines in Chinese literature, based on statistical data. Notably, educational theory and educational administration constitute the largest share, amounting to 34%. This implies that Chinese scholars concentrate on delving into educational theories linked to generative AI, exemplified by ChatGPT, and its implementation in educational administration. Subsequently, computer software and computer applications (31%) are succeeded by automation technology (17%), signifying that research on the methodological facets of the technology within these two disciplines is also highly regarded. Higher education, comprising 8%, implies a scholarly preference for applied research in this domain. The remaining disciplines exhibit a usage rate of less than 5%. Nevertheless, generative AI techniques are widely used in education and are applicable to a wide range of domains.
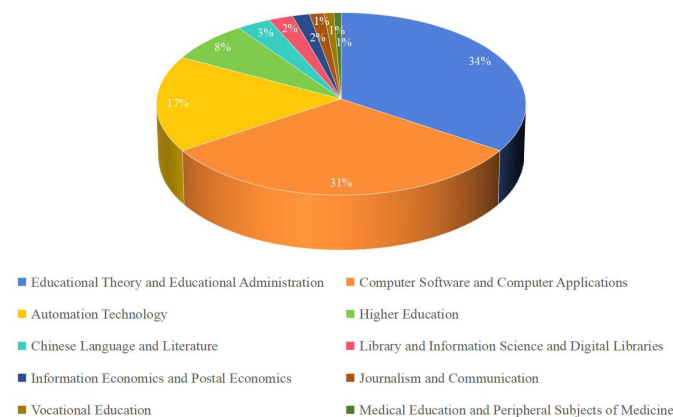

Fig. 3. Top 10 disciplines in CNKI.

3.2.2 Discipline distribution of English literature

The disciplinary distribution of the English literature retrieved from the WOS database for this study is illustrated in Fig. 4. The analysis suggests that research on the utilization of generative AI in education, represented by ChatGPT, has been associated with diverse fields in the past decade. These fields encompass education and educational research, computer science, engineering, surgery, chemistry, general internal medicine, health care sciences and services, science technology, environmental Sciences and ecology, and telecommunications. Education and educational research hold the largest share at 15%, followed by Computer Science and Engineering, constituting 14% and 13% of the disciplinary distribution, respectively. This suggests that research in this field is primarily led by educational research and encompasses technology development within the Computer Science and Engineering disciplines. Additionally, surgery, chemistry, general internal medicine, health care sciences and services, science technology, environmental sciences and ecology, telecommuni-

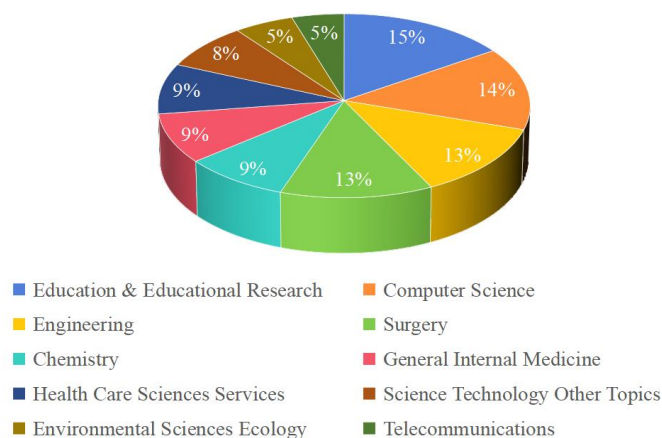cations, and other disciplines are pertinent to practical teaching and student learning research.

Fig. 4. Top 10 disciplines in WOS.

3.3 Analysis of core authors and institutions

3.3.1 Analysis of core authors and institutions in Chinese literature

a) Core authors: Conducted by CiteSpace, the visual mapping of the distribution of research institutions and authors is analyzed, unveiling that 214 Chinese core journal articles encompass 72 institutions and 64 authors. According to Price's theory, the formula $M \approx 0.749\sqrt{n_{max}}$ (Jiang, 2001) can determine the number of papers published by core authors. Here, n_{max} represents the number of papers published by the most productive authors in the research sample, and M represents the minimum number of papers published by the core authors. In this instance, n_{max} is 5. Thus, substituting the formula yields $M = 1.675$. Consequently, authors with more than two publications are categorized as core authors in this field. There are ten authors with more than two publications, and because of limited space, only the top three authors are presented in the text (see Table 1).

Betweenness Centrality is a crucial concept in network analysis as it measures the number of shortest paths passing through that node. This metric can aid in identifying key nodes in a network (Wang & Lu, 2020). In CiteSpace, nodes with a betweenness centrality greater than 0.1 are considered critical nodes, and the thicker their purple edges, the higher their mediator centrality, allowing users to visually identify important nodes in the network. Table 1 indicates that the centrality of the associated authors is low, all falling below 0.1. This implies that the research subjects within this field demonstrate relative independence, a lack of collaboration, and the absence of a stable core research team.

Through the integration of contextual data with frequency statistics and the examination of authors' collaborations, it is clear that Zhu and colleagues have conducted extensive studies on generative AI technology, which has the potential to enhance educational innovation and facilitate collaboration between humans and computers. The authors propose that the focal point of innovation in AI-generated content (AIGC), em-

Table 1. Statistics of top 3 authors in terms of number of published papers.

Ranking	Number of published papers	Centrality	Authors	Year
1	5	0.01	Zhiting Zhu	2023
2	3	0	Hongcai Wang	2023
3	3	0	Gaoqi Rao	2023

powering future learning paradigms, lies in highly aware and intentional generative learning. They explore the combination of algorithmic models and the relationship between different parts of AIGC to explain the underlying process and developmental requirements of highly conscious generative learning (Zhu et al., 2023). Zhao et al. (2023) propose a 'CORE' framework for designing educational prompts, including examples of structured prompt templates. The aim is to maximize the potential of the Large Language Model in education. Dai et al. (2023) investigated an intelligent questioning model based on ChatGPT. The authors proposed a '5W' questioning approach and developed a spiral questioning process, along with five dialogue types. These types are determined by the concept of 'cognitive needs-question openness'.

Regarding learning assessment, it is recommended that school education adopt a new methodology that prioritizes critical thinking over mere knowledge acquisition, emphasizes asking questions rather than providing answers, and favors logical reasoning over memory through repetition. This approach promotes the development of a flexible and adaptable mindset, which is more aligned with the demands of future society (Shen & Zhu, 2023).

Concentrating on the impact and challenges of ChatGPT on the traditional education model, as well as higher education, Wang (2023a) emphasized that universities can maintain their dominant position in knowledge and further realize their functions only by collaborating with society. Meanwhile, this presents a significant opportunity for the development of innovation and entrepreneurship education in China.

Rao (2023a) examined the practical application of ChatGPT and its ethical use in international Chinese language education. The researcher recommended using ChatGPT to enhance student communication skills and reduce teacher repetitive tasks. This would enable teachers to devote more time and energy to creating valuable content, expressing emotions, and promoting innovation. The primary ethical stance should prioritize instrumentalization while adhering to overarching principles such as the use of technology for the benefit of society, disclosure of identification, and focusing on the needs and well-being of humans (Rao, 2023b).

b) Article publishing institutions: Through the background statistics, noteworthy institutions with high publication volumes include the Faculty of Education of East China Normal University (6 papers), the School of Education Science of Nanjing Normal University (6 papers), PKU Graduate School of Education (5 papers), the Faculty of Education of Southwest University (5 papers), the School of Open Learning and Education of East China Normal University (5 papers),

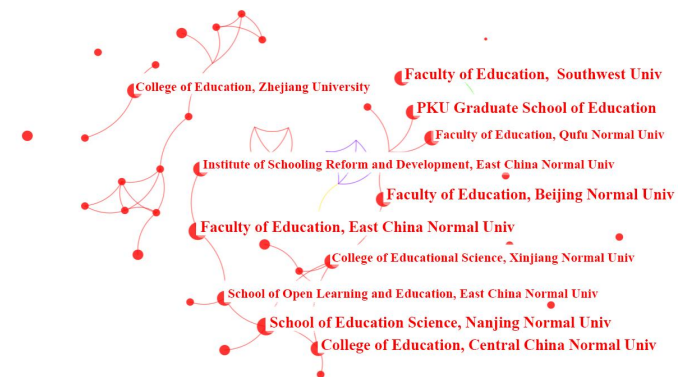and the Faculty of Education of Beijing Normal University (5 papers) and so on.

Fig. 5. Institutional co-occurrence network profile of Chinese research.

Fig. 5 illustrates the collaboration among institutions with a substantial number of articles in ChatGPT applied in education. The nodes in the figure represent the institutions, while the connecting lines indicate the cooperation between these institutions. As depicted in the figure, most of the core literature of Chinese research in this field emanates from normal universities and colleges. While there is some collaboration among research institutions, the degree of centrality is low, and a clear clustering relationship has not yet formed. This suggests that interdisciplinary cooperation in this field still requires strengthening.

3.3.2 Analysis of core authors and institutions in English literature

a) Core authors: Analysis of the visual mapping of research institutions and authors' distribution, conducted using CiteSpace and supported by background data, revealed that 144 English core journal articles engaged 90 institutions and 117 authors. The low centrality of the associated authors, all below 0.1 (see Table 2), indicates that the research entities in this field demonstrate relative independence and lack cooperation.

According to Price's theory, the calculation yielded M=1.498. The authors with a number of publications exceeding two are considered core authors in the field. There are a total of 17 authors with a statistical number of publications greater than 2, and because of limited space, only the top three are presented in the text (see Table 2).

Seth and Rozen led a team of writers who used generative AI approaches in multiple medical education research projects within this cohort. Their studies highlighted the practicality of

Table 2. Statistics of top 3 authors in terms of number of published papers.

Ranking	Number of published papers	Centrality	Authors	Year
1	4	0	Ishith Seth	2023
2	3	0	Isabel Herzog	2023
3	3	0	Warren M Rozen	2023

**Table 3**. Statistics of top 5 countries and regions in terms of number of published papers.

Ranking	Country/region	Number of published papers	Centrality	Year
1	USA	57	0.56	2020
2	China	20	0.18	2019
3	England	16	0.07	2020
4	Australia	10	0	2023

using extensive language models to promote independent and customized learning, as well as to provide clinical decision assistance to junior doctors. However, further advancements are needed to incorporate these models into education (Xie et al., 2024). The assessment of AI models' ability to generate realistic images of cosmetic surgery is conducted within the field of cosmetic surgery. The result suggests that incorporating artificial intelligence (AI) into cosmetic surgery can enhance patient education and training. However, it must be implemented rigorously and ethically to adhere to medical standards (Lim et al., 2023).

Gupta et al. (2023) investigated the viability of using ChatGPT for orthopedic education. Their findings suggest that ChatGPT is highly accurate and reliable when training orthopedic residents. The authors propose implementing this tool to improve educational curricula and enhance patient care quality.

Chinese researchers tend to focus on studying the impact of the application of generative AI technology. In contrast, English researchers are more inclined to conduct research specifically on applications represented by medical education.

b) Article publishing institutions: Fig. 6 illustrates the collaboration among institutions with a substantial number of publications in the field of ChatGPT applied in education. Evidently, the majority of the English core literature in this research field originates from medical universities, showcasing a certain level of cooperation between research institutions. Noteworthy institutions with high publication volumes include the University of Toronto, Harvard Med School, Peninsula Health, Monash University, the University of Michigan, Stanford University, Tsinghua University, etc. Each institution contributed three articles or more. Notably, the centrality of the University of Michigan and the University of Toronto exceeds 0.1, indicating that each institution has established a collaborative network centered on itself, covering multiple universities simultaneously.
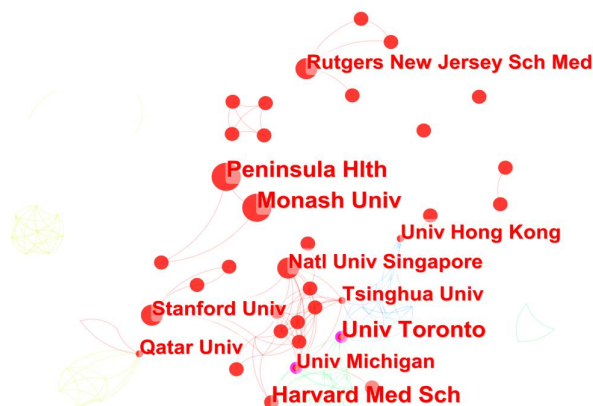
Fig. 6. Institutional co-occurrence network profile of English research.

Fig. 7. National cooperation profile of English papers.

3.4 Geographical distribution

Table 3 is obtained after counting the number and centrality of articles published by each country. CiteSpace is used to map the country's cooperation network (see Fig. 7).

The United States has the highest number of published papers, totaling 57 papers. China follows closely, contributing

In summary, the authors have published a relatively limited number of research papers on the integration of generative AI and education. These papers demonstrate different focuses.

20 papers and being the first country to initiate research in this field. The United States has the highest centrality of 0.56, closely behind Singapore, Italy, and Germany, respectively, with centralities of 0.33, 0.31, and 0.31. This indicates that these four countries have made remarkable contributions to the field and have published influential papers.
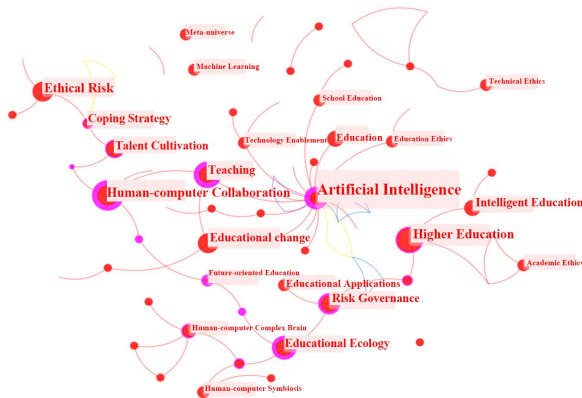

Fig. 8. High-frequency keywords co-occurrence profile of Chinese research.

4. Analysis of research hotspots

4.1 Hotspot identification based on keyword co-occurrence and clustering

A keyword serves as a brief and comprehensive representation of an article's content, indicating the primary research focus of the literature. The frequent use of a keyword indicates its prominence as a significant research area within the field. This study imports Chinese and English literature data into CiteSpace software. The keyword option in the node types column is selected to create the keyword co-occurrence and clustering map. In the keyword co-occurrence map, circles represent nodes, with the size positively correlated with the frequency of keyword occurrence. Connecting lines indicate correlations between keywords, and the colors of the map transition from purple to red over time. CiteSpace presents two indices in the keyword clustering map: modularity (Q value) and weighted mean silhouette (S value). These indices are derived from the network structure's clarity and clustering and are used to evaluate the effectiveness of mapping. The Q value ranges from 0 to 1, with a value greater than 0.3 indicating a significant clustering structure. Clustering is considered acceptable when the value of S is greater than 0.5 and significant when S is greater than 0.5. Clustering is deemed efficient and credible when the value of S surpasses 0.7 (Chen et al., 2015).

4.1.1 Analysis of Chinese research hotspots

The keyword co-occurrence map of Chinese literature (see Fig. 8) comprises 86 nodes and 81 connecting lines. Removing basic keywords like "AI", "Generative AI", "ChatGPT", and "Education", the analysis of Fig. 8 and background data reveals that these keywords, such as higher education, human-computer collaboration, educational change, ethical risk, risk

management, coping strategy, etc., appear five times or more. The centrality of these keywords exceeds 0.1, signifying heightened attention from the academic community. These topics have become hotspots and focal points in the current research field. Additionally, the smaller font-size keywords in the graph, such as talent cultivation, future education, and meta-universe, indicate that some scholars have also directed their attention to other topics. Most nodes and connecting lines in the graph predominantly appear in red, suggesting that these topics are primarily discussed in 2023.

Fig. 9 illustrates the keyword clustering map of Chinese literature. The Q value (0.7691) exceeds 0.3, and the S value (0.9598) surpasses 0.7. These values indicate that the knowledge structure depicted in this map is highly significant and characterized by both efficiency and reliability.
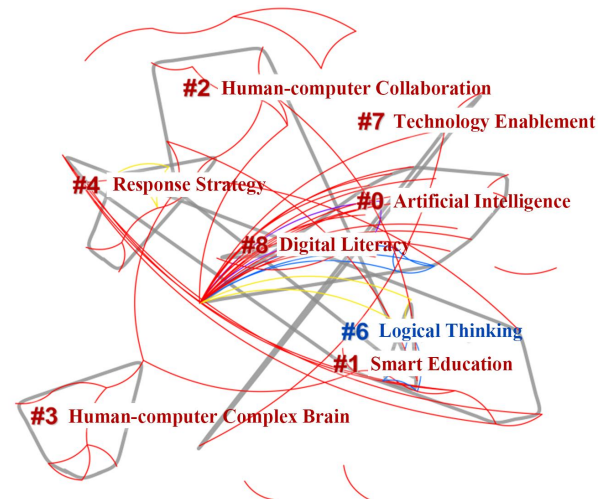

Fig. 9. High-frequency keywords clustering profile of Chinese research.

Through a comprehensive analysis of paper content, high-frequency keywords, high betweenness centrality terms, and keyword clustering, the following research hotspots in Chinese studies can be outlined.

a) Research on technology-enabled change in higher education: The clustering tags #0 Artificial Intelligence and #1 Higher Education in Smart Education reflect critical areas of application research in generative AI technology represented by ChatGPT. The advent of new technologies has introduced novel challenges to higher education, impacting curriculum design, teaching mode, teacher-student relationship, examination, evaluation, and even the organization and management system. Some individuals are concerned that the development of artificial intelligence could be viewed as a means of 'enslaving people', leading to the 'objectification' of individuals. However, historical evidence contradicts the notion that new technology hinders the progress of higher education teaching. On the contrary, the integration of new technology and tools has often facilitated the advancement of higher education instruction (Zhong, 2023). Consequently, the impact of new technologies, such as artificial intelligence, big data, VR/AR, and mobile technology, on society should be considered, along with the resulting changes in demand for talent. Higher

education should comprehensively consider training objectives by adjusting specializations and curricula, promoting changes in teaching modes and learning styles, improving management and decision-making efficiency, and facilitating the digital transformation of education (Zhong, 2023).

b) Ethical risks and technical limitations: Although generative AI technology, represented by ChatGPT, plays a significant role in various teaching scenarios, including learning, teaching, management, and evaluation, it still encounters numerous limitations. The system currently lacks proficiency in understanding information and evaluating its logical relationships, which may result in factual inaccuracies or the production of fraudulent information. These mistakes have the potential to misinform learners without specialized or relevant general knowledge. Additionally, the data used by ChatGPT, a form of generative AI technology, is complex and extensive. Therefore, the content generated by this technology may potentially infringe on intellectual property rights, exposing users to legal liabilities. Generative AI requires significant computing and storage resources for model training, testing, and adaptation to downstream tasks. However, the cost of meeting these requirements makes it financially unfeasible for a significant proportion of the education business (Lu et al., 2023).

c) Human teachers vs machine teachers: The clustering tags #1 Integration in Smart Education, #2 Teaching in Human-Machine Collaboration, and #4 Human Teachers in Response Strategies reflect the thoughts and concerns of the academic community regarding the subject of education and teaching under the impact of generative AI technology represented by ChatGPT. While artificial intelligence has the potential to encroach on the domain of human teachers, it can only partially replace skilled human educators. The critical question is not whether ChatGPT will replace educators but how current educators can take advantage of the opportunities offered by the ChatGPT era (Zhong, 2023). Recognizing the potential and utilizing the beneficial effects of ChatGPT is crucial in understanding user requirements, generating written material, fostering analytical thinking, and developing innovative abilities (Yang et al., 2023).

4.1.2 Analysis of English research hotspots

The English literature data are processed using CiteSpace software, resulting in the generation of a keyword co-occurrence network map (see Fig. 10) with a total of 133 nodes and 288 lines. After excluding keywords such as "artificial intelligence", "ChatGPT", and "Education", the top 5 high-frequency keywords include medical intelligence, medical education, large language model, machine learning, and natural language processing. Among these, medical education (18 papers), large language models (13 papers), machine learning (7 papers), natural language processing (6 papers), and patient education (6 papers) have become the most frequently mentioned topics. Notably, only the centrality of medical education, large language model, and patient education exceeds 0.1, indicating that English research in this field predominantly concentrates on issues related to generative AI technology and challenges within the realm of medical education. Analogous to Chinese

research trends, the primary topics in English research are predominantly discussed in 2023.
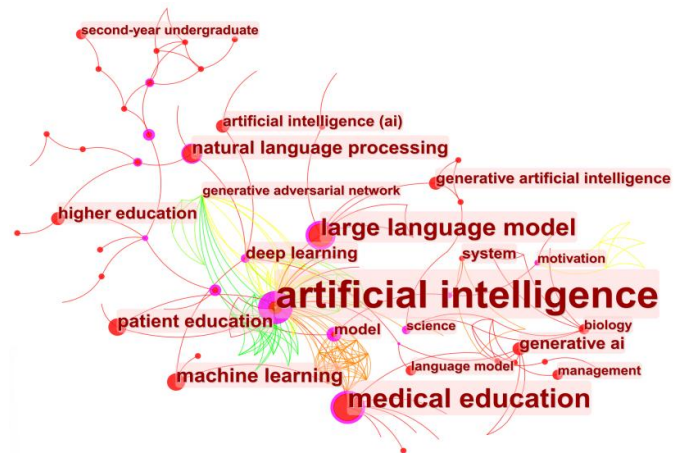

Fig. 10. High-frequency keywords co-occurrence profile of English research.

Fig. 11 displays the keyword clustering map of the English research literature. Notably, the Q value (0.7005) exceeds 0.3, and the S value (0.9275) surpasses 0.7. These values indicate that the knowledge structure depicted in this graph is highly significant, and characterized by efficiency and confidence.
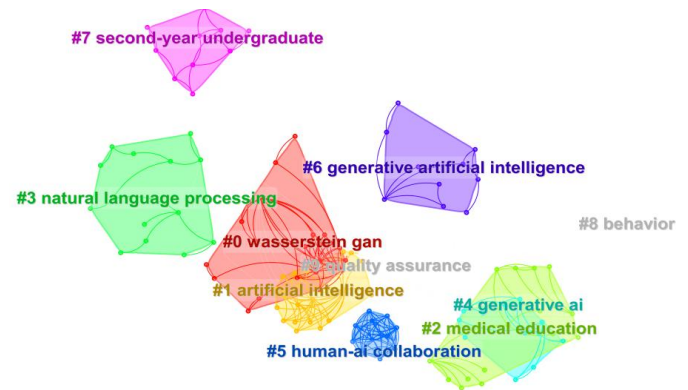

Fig. 11. High-frequency keywords clustering profile of English research.

Through a comprehensive analysis of article content, high-frequency keywords, high betweenness centrality words, and keyword clustering, the following research hotspots in English studies can be outlined.

a) Research in the field of medical education: The increased use of ChatGPT and other AI technologies in medical education is expected to be driven by technological improvements. As students and instructors become more skilled at integrating these technologies into their practices, their utilization is projected to grow (Choi et al., 2023). The use of ChatGPT raises several concerns, including ethical, copyright, transparency, and legal matters. Furthermore, there are potential risks associated with bias, plagiarism, lack of originality, inaccurate content leading to misunderstandings, limited knowledge, incorrect citations, network security issues, and the dissemination of information (Sallam, 2023).

b) Research in the field of higher education: Universities may face challenges keeping their writing and communication curricula relevant and up-to-date as artificial intelligence technologies like ChatGPT become more prevalent in professional contexts. It is essential to regularly evaluate and revise course content to equip students with abilities that complement artificial intelligence rather than skills that are being replaced by it. Meanwhile, generative artificial intelligence in professional writing jobs raises ethical concerns regarding authorship, plagiarism, and the presentation of AI-generated text as original work. To address these issues and promote the ethical use of AI, colleges must establish and enforce academic integrity rules and educate students accordingly (Okaiyeto et al., 2023).

c) Cooperation between humans and artificial intelligence: We are embarking on a new age of education and research centered on artificial intelligence. The incorporation of AI systems and chatbots in education should be seen as a chance for advancement rather than a source of concern (Kooli, 2023). ChatGPT is poised to be an invaluable resource for educators creating scientific lessons, rubrics, and quizzes. It can be used as a research tool to aid in editing and to experiment with enhancing the clarity of the study narrative (Cooper, 2023). For educators, it is important to thoroughly assess and modify any AI-generated material to suit their particular educational environments. In addition, the emergence of AI-generated characters will need to reassess the fundamental principles of human identity, including its development, safeguarding, and role in society (Pataranutaporn et al., 2021).

Keywords	Year	Strength	Begin	End	2018 – 2023
wisdom generation	2019	1.28	2019	2023	
future-oriented education	2021	0.69	2021	2021	
wisdom microteaching	2018	0.68	2018	2018	
microteaching	2018	0.68	2018	2018	
practice generation	2022	0.67	2022	2023	
potential risks	2022	0.67	2022	2023	
wisdom classroom	2022	0.67	2022	2023	
philosophy of education	2019	0.67	2019	2019	
domain	2019	0.67	2019	2019	
logical thinking	2019	0.67	2019	2019	

Fig. 12. Top 10 keywords in terms of strength of Chinese research.

4.2 Analysis of research trends based on burst words

Burst words are frequently occurring terms within a specific time frame, serving as indicators of research hotspots and potential future research trends during that period.

4.2.1 Analysis of Chinese research trends

Fig. 12 presents the top 10 keywords in Chinese literature based on burst intensity. It is evident that the keyword with the highest burst strength is "wisdom generation", which is 1.28. Additionally, scholars have shifted their focus from early-stage concerns about wisdom microteaching and the philosophy of education to issues related to practice generation, potential risks, and the wisdom classroom. Furthermore, the keywords within the top 10 exhibit a shorter burst period, indicating the diversity and variability of research hotspots within this topic. In contrast, the keyword with a slightly longer burst period is "wisdom generation", lasting five years.

4.2.2 Analysis of English research trends

Fig. 13 displays the top 20 keywords in English literature based on burst intensity. It is evident that the keywords with the highest burst intensity are generative adversarial networks, followed by teacher and deep learning, among others. Scholars have shifted their focus from the initial stage of technical and theoretical aspects, such as the generative adversarial network and deep learning, to the issues concerning teachers. Additionally, the keywords within the top 20 exhibit a short burst period, indicating the diversity and variability of research hotspots within this topic.

Keywords	Year	Strength	Begin	End	2013 – 2023
generative adversarial network	2019	1.7	2019	2021	
teacher	2022	1.24	2022	2023	
deep learning	2020	0.95	2020	2021	
privacy	2020	0.67	2020	2020	
agreement	2020	0.67	2020	2020	
wasserstein gan	2020	0.67	2020	2020	
implementation	2020	0.67	2020	2020	
facial feature	2020	0.67	2020	2020	
quality assurance	2020	0.67	2020	2020	
network	2019	0.65	2019	2019	
diffusion	2019	0.65	2019	2019	
glycan	2019	0.65	2019	2019	
green manufacturing technology	2019	0.65	2019	2019	
small sample size	2019	0.65	2019	2019	
wind energy	2019	0.65	2019	2019	
innovation	2019	0.65	2019	2019	
ovarian cancer	2019	0.65	2019	2019	
china	2019	0.65	2019	2019	
europe	2019	0.65	2019	2019	
deep neural network	2019	0.65	2019	2019	

Fig. 13. Top 20 keywords in terms of strength of English research.

5. Conclusions and suggestions

5.1 Conclusions

This paper systematically examines the current status and trends of Chinese and English research on the application of ChatGPT in education in recent years through visual mapping and generates the following conclusions:

Regarding the number of publications in this field, the emergence of ChatGPT contributed to explosive growth in the literature published in 2023. Cross-disciplinary research

on the application of generative artificial intelligence in education is increasingly reliant on the development of artificial intelligence technology. In the future, with the advancement of AI technology, scholars will increasingly prioritize research related to its applications.

Regarding the distribution of disciplines, a majority of research in this field is conducted within the realms of education and computer science. The range of disciplines involved is extensive, encompassing both technology-oriented disciplines and those focused on practical applications, such as automation technology, engineering, surgery, higher education, chemistry, etc.

Analyzing the situation of core authors and research institutions, the primary locus of research in this field is within universities, and much of the research is conducted with university support. However, given the cross-disciplinary nature of the research sample and the limited number of documents, collaboration among researchers is dispersed, a significant cooperative network is lacking, and there is insufficient communication and cooperation among core authors. The geographical distribution of research in this area indicates a low number of articles published in each country and highlights the need for strengthened cross-country cooperation.

In technology, prevalent technologies in this field include large language models, machine learning, and natural language processing. Regarding applications, higher education, medical education, and human-computer collaboration emerge as current research hotspots. In terms of research perspectives, English studies tend to be more micro, focusing on specific issues like technology and algorithms. Conversely, Chinese studies adopt a more macro perspective, emphasizing educational changes and ethical considerations in the application process.

Concerning research areas, Chinese and English studies exhibit distinct emphases, manifesting a divergent trend. In Chinese studies, scholars predominantly concentrate on the transformations in education induced by technological empowerment in higher education, alongside the ethical risks associated with it. Conversely, English studies prioritize the application of technology in the field of medical education, aiming to enhance the quality and effectiveness of medical education through technological means.

Regarding research trends, Chinese studies will delve into wisdom generation, practice generation, potential risks, and the wisdom classroom. Meanwhile, English research will transition from the initial exploration of technical, theoretical issues like generative adversarial networks and deep learning to the issues concerning teachers.

5.2 Suggestions

5.2.1 Strengthening interdisciplinary and transnational cooperation to form high-impact research teams

To fully leverage the potential of AI technology in education, relevant institutions and researchers should prioritize interdisciplinary research. It is crucial to strengthen the cooperation between AI and education specialists and foster cross-country and cross-linguistic collaboration between research

institutes. To enhance the academic impact of the field, it is recommended that relevant institutions and institutes should be established which facilitate interdisciplinary research teams to display their flexible application capabilities.

5.2.2 Exploring the application mechanism and potential of ChatGPT in different educational scenarios from multiple perspectives to promote human-robot collaboration

The generative AI technology represented by ChatGPT has ushered in an era of human-computer collaboration and intelligent teaching, which has given rise to robot teacher-student relationships, bringing convenient access to knowledge and personalized learning modes. Researchers should extensively explore the mechanisms and potentials of ChatGPT in various educational scenarios, such as knowledge learning, academic research, teaching, management, and evaluation, from the perspectives of learners, educators, and administrators to guide the application of ChatGPT in different scenarios and disciplines.

In addition, despite explosive growth, research in this field tends to focus on higher education and medical education. Researchers should pay more attention to the technological and personalized exploration of teaching and learning to promote educational reforms in basic education, adult education, mental health education, special education, etc.

5.2.3 Refining domains and developing specialized large language models to break down application barriers

The generative AI technology represented by ChatGPT still has limitations when it comes to meeting personalized needs in various educational scenarios due to the lack of pre-training. To address the specific challenges of the educational process, it is necessary to improve the existing models and cultivate specialized large language models for different educational scenarios, such as educational research models, instructional design models, subject knowledge models, mental health education models, and so on. Taking the mental health model as an example, the AI assistant would be built to provide users with efficient and professionally personalized services in the areas of professional knowledge query, scale production and analysis, individual tracking and observation, developmental problem counseling, and crisis prediction.

5.2.4 Enhancing ethical and risk studies and continuously improving relevant laws and guidelines

The application of ChatGPT in education encounters some challenges in promoting digital transformation, including ensuring educational equity, maintaining data security, and preventing infringement of intellectual property. Although some countries and international organizations have introduced laws and guidelines, governments should take the lead in enhancing relevant regulations in coordination with the rapid development of AI technology applications in their countries. Researchers should continue strengthening their research on specific ethical and risk issues to promote the instrumental application of AI. Users are expected to use AI tools appropriately and to avoid dependency, academic misconduct, and

other inappropriate behaviors.

In short, with the development of AI technology, there is an increasing amount of research and application of AI technology in the global education field, showing a trend of explosive growth and diversification, and various risks are gradually emerging. In the process of applying AI technology, countries should strengthen the development and application of professional models while simultaneously promoting risk avoidance.

Conflict of interest

The authors declare no competing interest.

References

Chen, Y. (2023). Beyond ChatGPT: Opportunities, risks, and challenges from generative AI. Journal of Shandong University (Philosophy and Social Sciences Edition), 3, 127-143.

Chen, Y., Chen, C., Liu, Z., Hu, Z., & Wang, X. (2015). The methodology function of CiteSpace mapping knowledge domains. Studies in Science of Science, 33(2), 242-253.

Choi, E. P. H., Lee, J. J., Ho, M. H., Kwok, J. Y. Y., & Lok, K. Y. W. (2023). Chatting or cheating? The impacts of ChatGPT and other artificial intelligence language models on nurse education. Nurse Education Today, 125(8), 105796.

Cooper, G. (2023). Examining science education in ChatGPT: An exploratory study of generative artificial intelligence. Journal of Science Education and Technology, 32(3), 444-452.

Dai, L., Zhao, X., & Zhu, Z. (2023). A new inquiry learning: Conversational learning with ChatGPT. Open Education Research, 29(6), 42-51+111.

Gupta, R., Park, J. B., Herzog, I., Yosufi, N., Mangan, A., Firouzbakht, P. K., & Mailey, B. A. (2023). Applying GPT-4 to the plastic surgery inservice training examination. Journal of Plastic, Reconstructive & Aesthetic Surgery, 87, 78-82.

Jiang, C. (2001). Price and scientometrics. Science of Science and Management of S&T, 22 (9), 20-22.

Kooli, C. (2023). Chatbots in education and research: A critical examination of ethical implications and solutions. Sustainability, 15(7), 5614.

Lim, B., Seth, I., Kah, S., Sofiadellis, F., Ross, R. J., Rozen, W. M., & Cuomo, R. (2023). Using generative artificial intelligence tools in cosmetic surgery: A study on rhinoplasty, facelifts, and blepharoplasty procedures. Journal of Clinical Medicine, 12(20), 6524.

Lu, Y., Yu, J., Chen, P., & Li, Mu. (2023). Educational application and prospect of generative artificial intelligence: Taking ChatGPT system as an example. Chinese Distance Education, 43(4), 24-31+51.

Okaiyeto, S.A., Bai, J.W., Xiao, H. W. (2023). Generative AI in education: To embrace it or not? International Journal of Agricultural and Biological Engineering, 16(3), 285-286.

Pataranutaporn, P., Danry, V., Leong, J., Punpongsanon, P., Novy, D., Maes, P., & Sra, M. (2021). AI-generated characters for supporting personalized learning and well-being. Nature Machine Intelligence, 3(12), 1013-1022.

Rao, G. (2023a). "ChatGPT is coming: New opportunities and challenges for international Chinese education" (Part A). Language Teaching and Research, 3, 1-14.

Rao, G. (2023b). Transformations and challenges triggered by ChatGPT-like AI in multiple fields. Journal of Tianjin Normal University (Social Science Edition), 3, 49-63.

Sallam, M. (2023). ChatGPT utility in healthcare education, research, and practice: Systematic review on the promising perspectives and valid concerns. Healthcare, 11(6), 887.

Shen, S., & Zhu, Z. (2023). ChatGPT-like products: Internal mechanism and its impact on learning evaluation. Chinese Distance Education, 43(4), 8-15.

Wang, H. (2023a). A philosophical review of ChatGPT in higher education. Chongqing Research on Higher Education, 11(4), 3-13.

Wang, H. (2023b). Challenges and opportunities of ChatGPT for education (Forum). Journal of Soochow University (Educational Science Edition), 11(2), 11-24.

Wang, W., & Lu, C. (2020). Visualization analysis of big data research based on Citespace. Soft Computing, 24(11), 8173-8186.

Xie, Y., Seth, I., Hunter-Smith, D. J., Rozen, W. M., & Seifman, M. A. (2024). Investigating the impact of innovative AI chatbot on post-pandemic medical education and clinical assistance: a comprehensive analysis. ANZ Journal of Surgery, 94(1-2), 68-77.

Yang, Z., Wang, J., Wu, D., & Chen, X. (2023). Exploring the impact of ChatGPT/AIGC on education and strategies for response. Journal of East China Normal University (Education Science Edition), 41(7), 26-35.

Zhao, X., Zhu, Z., & Shen, S. (2023). Educational prompt engineering: Constructing a new epistemological discourse in the era of digital intelligence. Chinese Distance Education, 43(11), 22-31.

Zhong, B. (2023). The challenges of ChatGPT to education. Chongqing Research on Higher Education, 11(3), 3-25.

Zhu, Z., Dai, L., & Hu, J. (2023). Higher consciousness generative learning: Innovation of learning paradigm enabled by AIGC technology. E-Education Research, 44(6), 5-14.