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A Bibliometric Analysis of Research on ChatGPT in Education

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Abstract

ChatGPT has become a prominent tool for fostering personalized and interactive learning with the advancements in AI technology. This study analyzes 212 academic research articles indexed in the Scopus database as of July 2023. It maps the trajectory of educational studies on ChatGPT, identifying primary themes, influential authors, and contributing institutions. By employing bibliometric indicators and network analysis, the study explores collaboration patterns, citation trends, and the evolution of research interests. The findings show the exponential growth of interest in leveraging ChatGPT for educational purposes and provide insights into the specific educational domains and contexts that have garnered the most attention. Furthermore, the study reveals the collaborative dynamics and intellectual foundations shaping the field by examining co-authorship and citation networks. This bibliometric analysis contributes to a comprehensive understanding of the current state of ChatGPT research in education, offering researchers and practitioners valuable insights into evolving trends and potential future directions for this innovative aspect of AI and learning.

Introduction

Artificial Intelligence (AI) applications exhibit substantial potential for enhancing both the pedagogical and instructional aspects of education (Farrokhnia et al., 2023; Xia et al., 2022). These technological tools facilitate educators in delivering pedagogically effective and adaptable instruction through personalized and adaptive teaching methodologies while concurrently furnishing tailored support to individual learners (Guan et al., 2020). Particularly noteworthy are AI-driven chatbots, which have witnessed frequent utilization of late, offering enhanced flexibility and diverse educational advantages (Cooper, 2023; Yang & Evans, 2019). The educational benefits of these tools have been extensively investigated across three key dimensions: learners, educators, and the overall educational system (Zawacki-Richter et al., 2019). Firstly, chatbots function as assistants, mentors, and tutors, delivering personalized feedback and guidance to learners (Fidan & Gencel, 2022; Wollny et al., 2021). Secondly, these AI applications alleviate the instructional burden on educators by dynamically assessing learners' progress (Celik et al., 2022; Jeon, 2021). Lastly, chatbots provide educational administrators with access to institutional-level information, facilitating institutional comparisons and informed decision-making (Zawacki-Richter et al., 2019).

The incorporation of such tools has emerged as a prominent topic within educational settings, notably following the introduction of the Generative Pre-trained Transformer-3 (GPT-3) (Farrokhnia et al., 2023). GPT-3, developed

by OpenAI, a San Francisco-based artificial intelligence research laboratory, represents the third iteration in the GPT-n series of language prediction models (Swathi & Gopalreddy, 2023). Another noteworthy development from OpenAI, ChatGPT, stands as a cutting-edge pre-trained language model that has garnered considerable attention. Its remarkable language comprehension and text generation capabilities result from extensive training on expansive datasets, enabling it to amass an almost exhaustive knowledge repository. ChatGPT adeptly produces detailed responses to prompts and subsequent queries (Haleem et al., 2022). The potential of ChatGPT extends to improving information accessibility, facilitating personalized and intricate learning experiences, and alleviating the workload on educators, thereby enhancing efficiency in essential processes and tasks (Farrokhnia et al., 2023). Moreover, ChatGPT has contributed to the increased popularity of AI-driven chatbots, fostering accessibility, personalized learning, and learner collaboration owing to their natural language interaction capabilities (Cotton et al., 2023).

In educational contexts, ChatGPT and similar language models extend substantial support across diverse tasks, encompassing activities such as the design of assessments, generation of essays, and language translation. Additionally, these models proficiently manage tasks, including answering questions, summarizing texts, and engaging in conversational interactions reminiscent of peer engagements (Sok, 2023). These tools exhibit adaptability, enhancing interactions based on user input to optimize their efficacy (Nguyen et al., 2022).

The incorporation of ChatGPT and similar language models in higher education, as advocated by Atlas (2023), presents notable advantages across varied contexts, spanning language acquisition, research endeavors, and administrative functions. Consequently, it is reasonable to posit that ChatGPT holds considerable potential as a valuable educational instrument (Polat, 2023). Moreover, these models demonstrate the capacity to simulate human cognitive processes, encompassing problem-solving, contextual reasoning, estimation, planning, and decision-making (Boucher et al., 2021; Nadarzynski et al., 2019). Despite several studies delving into these and related facets, research in this domain remains constrained (Huang et al., 2023; Kuhail et al., 2023; Zhang et al., 2023).

Given the pronounced impact and widespread utilization of ChatGPT and analogous applications, further research becomes imperative for a more profound understanding of their effects (Farrokhnia et al., 2023; Wu & Yu, 2023). To address potential gaps in the literature and achieve a comprehensive grasp of the research landscape, conducting a bibliometric analysis focusing on ChatGPT becomes indispensable. While a previous study offers a rapid review of this topic (Lo, 2023), the current investigation aims to delve more deeply and furnish detailed insights to illuminate the existing studies in this field.

AI and ChatGPT in Education

Artificial intelligence encompasses various technologies and methodologies, such as machine learning, natural language processing, data mining, neural networks, and algorithms (Zawacki-Richter et al., 2019). It has been defined in various ways, with some definitions emphasizing the skills or capabilities present in digital computers. According to Baker and Smith (2019), AI refers to the capacity of computers to perform cognitive tasks akin to

human minds, particularly in learning and problem-solving. AI plays a critical role in various fields, including health, education, and engineering (Polat, 2023).

In education, the literature encompasses diverse review studies on AI, each with a distinct focus. Ouyang et al. (2022), for instance, conducted a review centered on empirical research exploring the applications of AI in online higher education, while Xu and Ouyang (2022) delved into the utilization of AI technology, specifically in STEM education. Similarly, Zhai et al. (2021) executed a systematic review of educational AI tools, aiming to scrutinize prevalent issues and trends in the educational landscape, whereas Salas-Pilco et al. (2022) presented a systematic study on the incorporation of AI in teacher education.

Although these reviews primarily emphasize education, many studies have focused on specific disciplines within education. Examples include reviews focused on children's education (AalSaud, 2021; Crescenzi-Lanna, 2023), mathematics education (Hwang & Tu, 2021), nursing education (Buchanan et al., 2021; Harmon et al., 2021), medical education (Chan & Zary, 2019; Iqbal et al., 2021), and computer science education (Francisco & de Oliveira Silva, 2022). Furthermore, several review studies have adopted a narrow scope by concentrating on specific regional or contextual aspects rather than providing a more general reflection on the body of studies. For instance, Salas-Pilco and Yang (2022) conducted a systematic review of AI applications with a focus on Latin American higher education, Alzahrani (2022) explored the use of AI in education within the Arab world, and Durso and Arruda (2022) limited their review to Brazilian studies on AI in distance education.

Indeed, these studies provide a comprehensive perspective on the broader application of AI in education, with a notable focus on the overarching impact rather than concentrating on specific tools. Notwithstanding, some research has chosen to delve into particular facets, such as the work of Chu et al. (2022), which centered on AI-based robots, and the systematic review by Okonkwo and Ade-Ibijola (2021), examining studies on the use of Chatbots in education.

Since the introduction of ChatGPT in November 2022, it has emerged as a central topic in educational discourse and research, offering substantial advantages in educational settings (Polat, 2023). It is a versatile tool, acting as a teaching assistant by designing instructional materials and functioning as a virtual tutor for students by addressing queries and facilitating collaboration (Rudolph et al., 2023). However, this technology has also presented challenges, including the potential for generating incorrect or fabricated information and plagiarism-related issues (Sallam, 2023). Furthermore, ChatGPT exhibits certain limitations, such as a limited depth of understanding of language, the potential to produce biased content, an inability to assess the credibility of training data, and constraints in handling content that requires higher-order thinking skills (Farrokhnia et al., 2023). Given these considerations, a review of studies investigating ChatGPT can provide valuable insights into its applications and limitations in educational settings.

Related Studies

Review studies play a crucial role in synthesizing literature, offering a comprehensive overview of ChatGPT in

education, and consequently identifying potential avenues for future research. The existing review studies investigating the utilization of ChatGPT are predominantly limited in scope, with primary focuses on medical education, language teaching, and academic writing. Notable examinations include inquiries into ChatGPT in medical education (Eggmann et al., 2023; Ruksakulpiwat et al., 2023; Sallam, 2023; Sharma et al., 2023), language teaching (Jeon et al., 2023; Kohnke et al., 2023), academic writing (Huang & Tan, 2023; Imran & Almusharraf, 2023; Mojadeddi & Rosenberg, 2023; Qureshi et al., 2023), and education in general (Lo, 2023; Mhlanga, 2023). These reviews emphasize the need for more comprehensive investigations into the various applications of ChatGPT in education, highlighting the potential for further advances in this evolving field.

Regarding medical education, recent studies have collectively explored ChatGPT's diverse applications in various healthcare domains. Eggmann et al. (2023), for example, focused on dental medicine, recognizing the potential for decision support, text summarization, writing efficiency, and multilingual communication. However, they underscored the importance of careful consideration due to occasional inaccuracies and misinformation risks. Ruksakulpiwat et al. (2023) systematically reviewed ChatGPT's role in medical research, highlighting its transformative potential in drug development, medical report enhancement, information provision, research conduct improvement, and personalized medicine. Despite its promise, concerns related to accuracy, originality, academic integrity, and ethical implications were emphasized, urging careful integration into clinical research and medical practice. Sallam (2023) systematically reviewed ChatGPT's contributions to healthcare education, research, and practice, recognizing benefits such as improved scientific writing, enhanced research equity, and practical healthcare applications. However, ethical considerations, including copyright issues, legal concerns, risks of bias, and plagiarism threats, were highlighted, stressing the importance of ethical guidelines. Lastly, Sharma et al. (2023) explored ChatGPT's potential to address the shortage of diabetes educators and the limitations of traditional methods. While acknowledging the benefits of tailored and interactive education, the study emphasized the necessity for additional research to confirm effectiveness and underlined the importance of ethical development to maximize benefits and minimize risks in integrating ChatGPT into diabetes education and clinical practice. Together, these studies provide a nuanced perspective on the potential and challenges of leveraging ChatGPT across diverse healthcare domains.

The promising status of chatbots and ChatGPT in language education is also reflected in review studies. Jeon et al. (2023), for example, reviewed 32 studies on chatbots that use speech recognition for language learning. The study noted a rising trend in the use of these chatbots, particularly in the year 2022. The majority of the participants were college students, mainly studying English. The studies focused on how the participants perceived the chatbots. They mostly used a single-chatbot design in classrooms or labs over a month. Smartphones and tablets were the common devices, highlighting the chatbots' value as conversational partners for improving language proficiency.

Additionally, Kohnke et al. (2023) conducted a study on the potential of ChatGPT in language teaching. They proposed various ideas for using the tool and addressed debates surrounding it. The study emphasized the significance of AI in education and highlighted the need for advanced digital competence. ChatGPT was evaluated as a versatile tool for language learning, and its pedagogical possibilities were discussed. The study highlighted

the tool's role in adaptive language learning. These studies underscore the changing landscape of language learning where speech-recognition chatbots and ChatGPT enhance proficiency.

Artificial intelligence tools like ChatGPT can significantly improve the efficiency and quality of writing articles for scientists as they accelerate the writing process, develop outlines, add details, enhance overall writing style (Huang & Tan, 2023), assist with formatting and translation (Mojadeddi & Rosenberg, 2023). It is essential to remain mindful of ChatGPT's constraints, necessitating a thorough review and editing of generated text to prevent issues like plagiarism and fabrication (Huang & Tan, 2023). Moreover, considerations should extend to its limitations, encompassing inaccuracies and biases (Mojadeddi & Rosenberg, 2023). Non-content experts are strongly advised to exercise great caution when utilizing these tools since, while the output may seem valid superficially, a significant portion is erroneous and demands active verification (Qureshi et al., 2023). Adopting ChatGPT as a writing assistant in the educational process, particularly academic writing, presents both opportunities and challenges, emphasizing the importance of recognizing its role as a beneficial aid and facilitator for both learners and instructors in easing and supporting the academic process (Imran & Almusharraf, 2023). While ChatGPT and LLMs hold promise in assisting with writing tasks, the technology is still in its early stages and requires substantial development for practical application in such contexts (Qureshi et al., 2023).

Studies on the use of ChatGPT in education in general are quite limited. Mhlanga (2023), for example, aimed to provide a comprehensive analysis of the responsible and ethical usage of ChatGPT in education from a lifelong learning perspective, encouraging further study and debate while emphasizing the importance of privacy, fairness, non-discrimination, and transparency. Additionally, Lo (2023) sought to enrich our understanding of ChatGPT's capabilities across subject domains, its potential applications in education, and the challenges identified by researchers. The review results revealed mixed findings, with some areas being outstanding (e.g., economics), some being satisfactory (e.g., programming), and others unsatisfactory (e.g., mathematics). Despite its potential to assist instructors in generating course materials, providing suggestions, and serving as a virtual tutor for students by answering questions and facilitating collaboration, challenges such as generating incorrect or fake information and bypassing plagiarism detectors were noted. These studies underscore the need for further research and thoughtful consideration of the ethical implications of integrating ChatGPT into educational settings.

In conjunction with the review studies, Pradana et al. (2023) employed systematic review and bibliometric analysis methods to investigate the use of ChatGPT in education. The analysis incorporated 74 studies gathered from Google Scholar, and VOSviewer software was utilized for bibliometric data analysis. The study revealed a growing trend in using ChatGPT in education, identified key contributors to the field, explored related research topics, and provided suggestions for future research directions. While this study offers certain implications for integrating ChatGPT into educational processes, it falls short of providing a comprehensive framework for the subject. Consequently, it is necessary to identify descriptive characteristics of research on ChatGPT in education, influential research in this domain, core terms associated with ChatGPT in education research, and current research themes along with future research directions. Therefore, a comprehensive review of current studies is essential to offer updated and holistic insights into ChatGPT's educational applications. In this regard, the present study aims to summarize its use in educational settings and present the emerging trends in research examining

ChatGPT in education by addressing the following research questions:

1. What are the descriptive characteristics of research on ChatGPT in education?
2. What is the influential research on ChatGPT in education?
3. What are the core terms of research on ChatGPT in education?
4. What are the current research themes and future research directions of research on ChatGPT in education?

Method

Research Design

This study employed bibliometric analysis to uncover distribution patterns and trends in ChatGPT usage in educational research. Bibliometric analysis is a reliable technique (Hood & Wilson, 2001) that explores critical aspects and emerging topics in a specific field (Donthu et al., 2021). This method visually represents linkages among key concepts in a research topic, aiding researchers' understanding of these relationships (Heersmink et al., 2011). Many researchers have used this method to explore research trends across various domains, such as applying it to analyze AI in education (e.g., Pradana, 2023; Song & Wang, 2020).

The technical framework proposed by Donthu et al. (2021) guided the research questions: (1) performance analysis and (2) science mapping. Performance analysis examines the contributions of research constituents, while science mapping delves into the relationships between these constituents (Donthu et al., 2021). Performance analysis encompasses various research constituents familiar in review studies, such as authors, institutions, countries, and journals. Science mapping techniques, on the other hand, involve citation analysis, co-citation analysis, bibliographic coupling, co-word analysis, and co-authorship analysis. In this regard, this study's first two research questions focus on performance metrics regarding the use of ChatGPT in education. In contrast, the third and fourth questions employ science mapping techniques. Additionally, the R-studio program with open-source bibliometrix packages was chosen for detailed science mapping and bibliometric analysis visualizations (Aria & Cuccurullo, 2017).

Dataset

Using data from different databases in bibliometric evaluation exercises may lead to divergent results (Singh et al., 2021). Therefore, selecting the appropriate database is essential. In this study, the Scopus database was searched comprehensively, including all years and categories, for bibliometric mapping analysis. Scopus was chosen exclusively due to its wide acceptance as a comprehensive bibliographic database in academia (Zhu & Liu, 2020), publishing research papers with strong theoretical and scientific foundations.

On July 11, 2023, a search was conducted in the title, abstract, and keyword fields of Scopus using the following search string ("chatgpt" AND ("education" OR "instruction" OR "teaching" OR "learning")). The initial search generated 318 records, which were subsequently filtered based on document type (article, review, conference paper, book chapter) and language (English), resulting in a final set of 212 records. The study selection process is

illustrated in Figure 1.

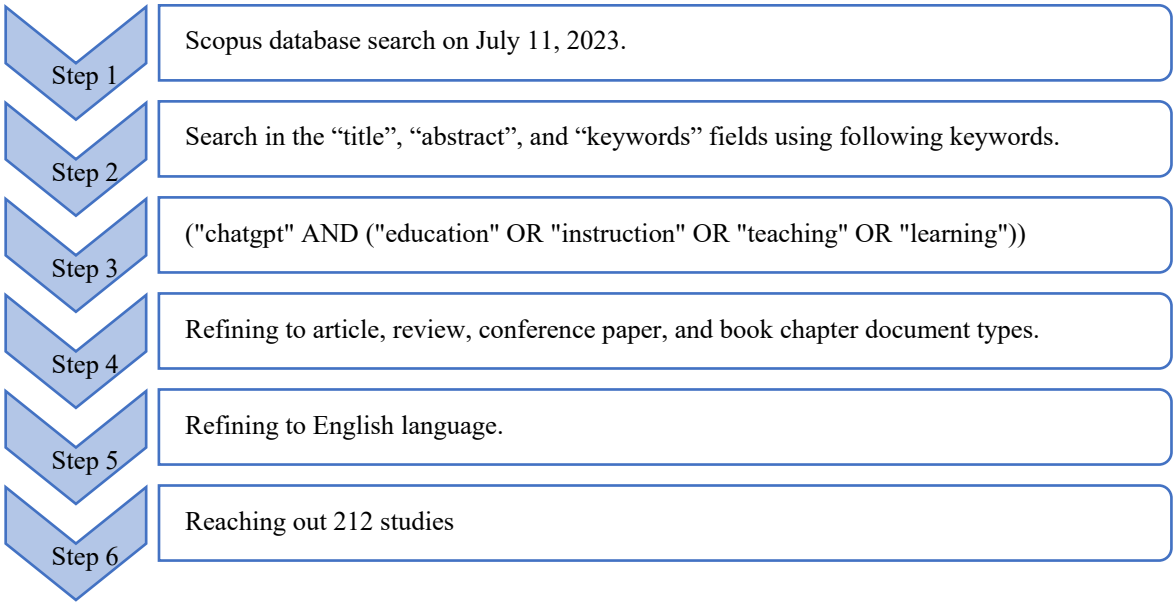

Figure 1. Study Retrieval Process

Data Analysis

First, we generated BibTex files containing all the data from the Scopus core collection. Then, we employed the biblioshiny web interface within RStudio along with the bibliometrix package to carry out a bibliometric analysis and visualization. With this package, we could create various visual representations, including tables and graphs, using a user-friendly interface without requiring any coding expertise.

The data analysis process consisted of four stages: descriptive, influential, core, and conceptual aspects of the topic. The first stage examined the research field, revealing its descriptive characteristics and an overview of research topics based on the authors’ country. In the second stage, we analyzed influential factors such as sources, articles, authors, affiliations, institutions, and countries that significantly impacted the use of ChatGPT in education within the chosen timespan. The third stage focused on commonly used keywords, evaluating the field’s knowledge structure by analyzing keyword plus and author keywords. The final stage examined the field’s conceptual foundation by analyzing the interaction of knowledge structures and conducting a thematic evaluation. During the third and last stage of the analysis, irrelevant authors’ keywords and keywords plus that lacked individual significance were disregarded. Furthermore, synonymous terms and expressions were consolidated. The excluded and merged terms are listed in Appendix for reference.

Results and Discussion

Descriptive Characteristics of Research on ChatGPT in Education

The analysis of the Scopus core collection revealed 212 publications on the use of ChatGPT in education literature

between 2022 (n=1) and 2023 (n=211). The discovery of only one study in 2022, followed by a significant increase to 211 studies in 2023, indicates that the field is relatively new and experiencing a growing trend (Imran & Almusharraf, 2023). Due to the nature of the obtained records being limited to the past two years, we could not find definitive evidence regarding the distribution of the subject across multiple years.

Table 1. Descriptive Characteristics of Studies on ChatGPT in Education

Description	n	%
Documents	212	100
Timespan		
2022	1	0.5
2023	211	99.5
Types		
Research article	162	76.4
Review article	27	12.7
Conference paper	21	9.9
Book chapter	2	0.9
Keywords		
Keywords Plus (ID)	724	-
Author's Keywords (DE)	622	-
Authors		
Single-authored	47	5.8
Multi-authored	763	94.2
Total number of authors	810	100
International co-authorships	56	26.42
Avg. of co-authors per doc	3.96	-

Research articles accounted for a great portion (76.42%) of the selected publications, followed by reviews (12.74%), conference papers (9.91%) and book chapters (0.9%). When evaluated in terms of publication processes, it is interesting that the number of research articles expected to take longer is higher. This may be a result of the fact that Scopus is a journal-oriented database. Additionally, the findings emphasize how crucial the Scopus database is for researchers seeking bibliographic materials pertinent to their study subject (Río-Rama et al., 2018). In this sense, future review studies can be conducted by including more different databases (Zawacki-Richter et al., 2019) and focusing on conference proceedings published faster to see the trend.

These publications encompassed a total of 724 keywords plus and 622 author keywords. Although author keywords are generally assumed to be more than keyword plus, it is seen that the opposite is the case in this study. This is most likely because it is a new topic requiring further research (Sakirin & Said, 2023). On average, each publication had four co-authors (n=3.96), with collaborative authorship observed in academic papers (77.83%). Additionally, international co-authorship was identified in more than one-fourth of the publications within the author's network of collaborators.

Influential Research on ChatGPT in Education

Influential Sources

Source Impact and Bradford Law were utilized to identify the core journals in this field. Table 2 lists journals based on their g-index, h-index, m-index, total citations (TC), and net production (NP). In descending order according to the g-index, which is an author-level metric, the three most influential sources in the field are the JMIR Medical Education, Journal of Applied Learning and Teaching, and Journal of University Teaching and Learning Practice.

Table 2. Source Impact of the Most Influential Journals

Top Influential Sources	g_index	h_index	m_index	TC	NP
JMIR Medical Education	5	3	3	67	5
Journal of Applied Learning and Teaching	4	4	4	23	6
Journal of University Teaching and Learning Practice	4	2	2	25	4
Contemporary Educational Technology	3	2	2	15	3
Innovations in Education and Teaching International	2	2	2	25	2
Education Sciences	2	2	2	15	2
Sustainability (Switzerland)	2	2	2	7	2

Table 3. Sources Categorized According to the Bradford's Law

Sources	F	CF	Zone
Journal of Applied Learning and Teaching	7	7	Zone 1
JMIR Medical Education	5	12	
Journal of Chemical Education	5	17	
Journal of University Teaching and Learning Practice	5	22	
Sustainability (Switzerland)	4	26	
British Journal of Educational Technology	3	29	
Computers and Education: Artificial Intelligence	3	32	
Contemporary Educational Technology	3	35	
Education and Information Technologies	3	38	
Electronics (Switzerland)	3	41	

Note: F = citation frequency, CF = cumulative citation frequency.

On the other hand, Table 3 provides the ten higher-ranking sources based on Bradford's Law that categorize journals into three zones. Of the 155 journals analyzed, 24 were identified as course sources involved in Zone 1, demonstrating their importance in the research of the ChatGPT in education (Bommineni et al., 2023). Additionally, 62 sources were placed in Zone 2 and 69 in Zone 3. The Journal of Applied Learning and Teaching achieved the top position in Zone 1, followed by JMIR Medical Education and Contemporary Educational Technology.

Influential Articles

The list of the leading ten articles in the selected timespan is presented in Table 4. It is clear that four primarily concentrated on medical education, three on academic writing, two on general education, one on media education, and one on higher education.

Table 4. Most Globally Cited Documents

Author (year)	TC	NTC	Domain	Purpose
Gilson et al. (2023)	49	17.92	Medical education	This study assesses the effectiveness of ChatGPT in performing medical question-answering tasks.
Dwivedi et al. (2023)	42	15.36	Education, business, society	This study explores the opportunities, challenges, and implications associated with generative AI technologies like ChatGPT in the domains of education, business, and society.
Pavlik (2023)	39	14.26	Media education, journalism	This study shows the capabilities and constraints of ChatGPT while providing insightful reflections on the impact of generative AI on journalism and media education.
Salvagno et al. (2023)	32	11.70	Academic writing	This paper examines the utilization of the ChatGPT in the context of scientific writing.
Sallam (2023)	30	10.97	Medical education, Academic writing	This review explores the potential future applications of ChatGPT in diverse domains, including healthcare education, academic/scientific writing, healthcare research, and healthcare practice.
Huh (2023)	21	7.68	Medical education	This study compares the knowledge and interpretation ability of ChatGPT with medical students in Korea by administering a parasitology examination to both groups.
Cascella et al. (2023)	20	7.31	Medical education	This study examines the feasibility of ChatGPT in clinical and research contexts, specifically exploring its potential applications in supporting clinical practice, enhancing scientific production, mitigating misuse in medicine and research, and facilitating reasoning on public health topics.
Tlili et al. (2023)	17	6.22	Education	This study examines the concerns associated with the utilization of chatbots, particularly ChatGPT, in education.
Macdonald et al. (2023)	17	6.22	Academic writing	This study shows the potential of ChatGPT in assisting researchers to expedite the process of drafting their papers.
Cotton et al. (2023)	16	5.85	Higher education	This paper explores the opportunities and challenges of incorporating ChatGPT in higher education while examining the potential risks and rewards associated with these tools.

Note: TC = total citation, NTC = normalized total citation

As seen in Table 4, studies investigating ChatGPT in medical education are leading. Such a higher proportion of studies in medical education may be a source of inspiration for future studies to investigate why ChatGPT stands out in the field of health education. For instance, Sallam (2023) conducted a review study on the use of ChatGPT in health education in which he analyzed 60 studies and grouped the benefits of ChatGPT to health education under five factors: (i) academic/scientific writing, (ii) benefits in scientific research, (iii) benefits in healthcare practice, (iv) educational benefits in healthcare disciplines, and v) free availability. However, these factors are common to the field of health education. Therefore, examining the use of ChatGPT in other subjects is essential.

Upon analyzing the purpose statements of these studies, they primarily emphasize potentials, opportunities, and concerns about ChatGPT in education. The fact that those studies are initial research is regarded to be the key reason why they concentrated on these areas. However, the number of application studies in further studies is expected to rise in line with these opportunities and concerns. Furthermore, Lo (2023) suggests that ChatGPT has several challenges regarding its application towards its potential to serve as an assistant for teachers and a virtual tutor for learners. As a result, more research into ChatGPT applications is urgently required (Ali et al., 2023; Sakirin & Said, 2023).

Influential Authors, Affiliations, and Countries

This section provides a comprehensive overview of the key authors, organizations, institutions, and countries that have made notable contributions to the field. Table 5 presents the top five influential authors in this field, determined by their h-index score. As the table shows, these influential authors exhibit comparable academic characteristics, suggesting that the topic is still novel. These results are inconsistent with those of Prada et al. (2023), revealing the top most productive writers, which probably results from the fact that this study analyzed more and more recent studies.

Table 5. Most Influential Authors

Author	h_index	g_index	m_index	TC	NP
Strunga, M.	2	2	2	10	2
Surovková, J.	2	2	2	10	2
Thurzo, A.	2	2	2	10	2
Urban, R.	2	2	2	10	2
Tan, S.	2	2	2	8	2

Note: TC=total citation, NP=net production.

The countries and organizations most cited and productive in using ChatGPT in education literature are ranked in Table 6. The United States (USA) and the United Kingdom (UK) emerged as the leading countries regarding production and citation impact, respectively. It is also worth noting that Belgium, Korea, Canada, Malaysia, and Hong Kong are in the top 10 most cited countries, although they are outside the top 10 regarding the number of publications. In addition, Monash University ranked first among the relevant affiliations in the given context.
Figure 2 illustrates the top 10 countries of corresponding authors in the field. MCP is an abbreviation for multiple

country publications, indicating studies where researchers from more than one country have collaborated. On the other hand, SCP stands for single-country publications, representing studies conducted solely within one country. For a study to be categorized as an MCP, it must involve at least one researcher from a foreign country.

Table 6. Influential Countries by Scientific Production and Citations

Scientific Production		Most Cited Countries		Relevant Affiliation	
Country	f	Country	TC	Organization	Article
USA	148	USA	89	Monash University	5
Australia	53	UK	86	Charles University	4
UK	47	Belgium	32	Swansea University	4
China	35	Jordan	30	The University of Queensland	4
India	34	Italy	23	University of Bern	4
Germany	21	Korea	21	University of Galway	4
Peru	18	Canada	18	University of Tasmania	4
Italy	17	Australia	12	Cedars-Sinai Medical Center	3
Jordan	15	Malaysia	12	Fudan University	3
Switzerland	11	Hong Kong	11	Institute of Automation	3

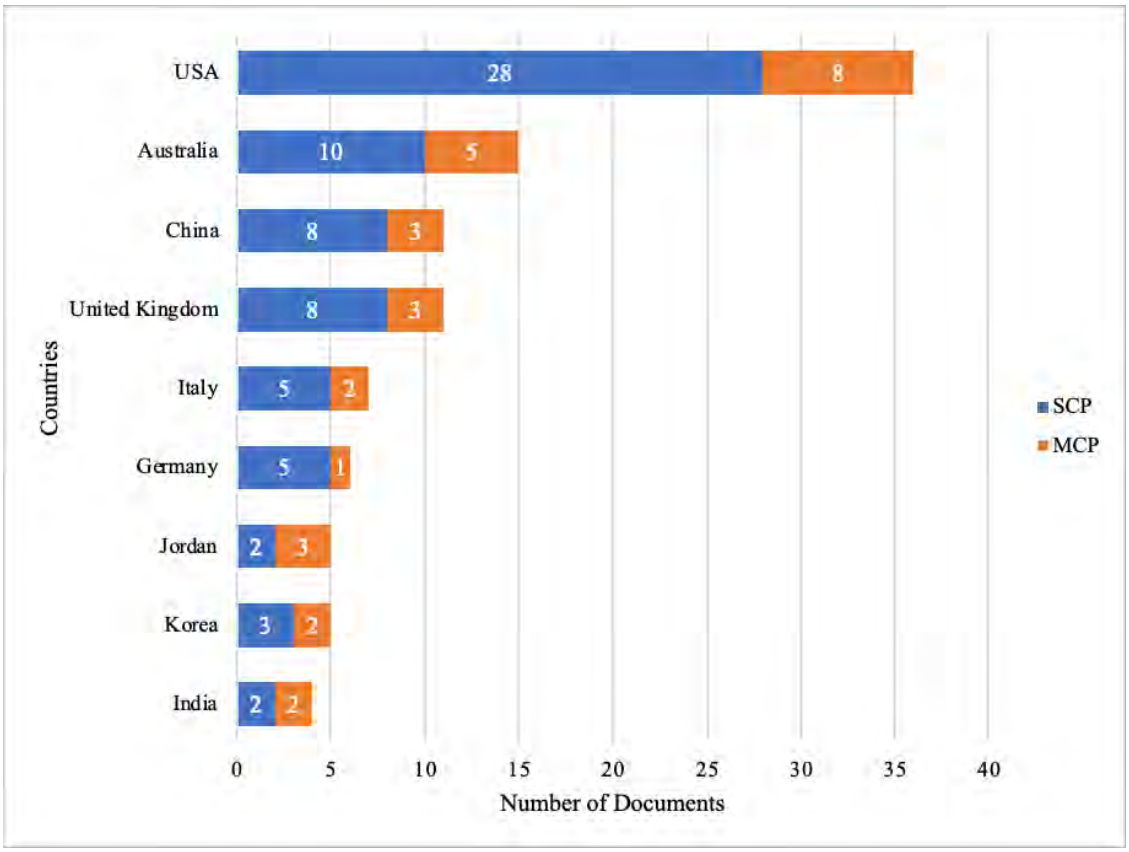

Figure 2. Top Ten Countries of Corresponding Authors

As seen in Figure 2, the USA is the leading country for corresponding authors, publishing 36 articles with 28

SCPs and 8 MCPs, followed by Australia and China. Australia has 15 articles (10 SCPs and 5 MCPs), while China ranks third in overall article count. On the other hand, it is seen that Peru and Switzerland, which are in the top 10 according to the number of studies in Table 6, are outside the top 10 according to the number of corresponding authors in Figure 2. In addition, it is also clear that general and country-based SCPs are weighted more than MCPs.

Core Terms of Research on ChatGPT in Education

Table 7 lists the top ten terms frequently used in literature. It includes two units of analysis: "keyword plus (ID)" and "author's keywords (DE)." IDs, which stands for "*Identifier*" or "*Keyword Plus*," are generated algorithmically from cited reference titles, while DEs, which stand for "*Descriptors*" or "*Author's Keywords*," are directly provided by the authors (Zhang et al., 2016). Although both are valuable for bibliometric analysis, IDs may not represent the article content thoroughly. Therefore, the findings from both units of analysis are considered.

Tablo 7. Most Frequently Used Keywords

Keywords Plus (ID)			Author's Keywords (DE)		
Themes	Words	f	Themes	Words	f
Computational intelligence	Artificial intelligence	62	Conversational agents	ChatGPT	134
	Machine learning	13		Chatbots	28
	Deep learning	11	Computational intelligence	Artificial intelligence	111
Human learning	Human	49		Machine learning	26
	Education	12		Generative AI	17
Language processing	Natural language processing	21	Language processing tools	Large language models	29
	Language model	17		Natural language processing	26
	Language processing	11	Educational domains	Education	23
Conversational agents	ChatGPT	23		Higher education	12
	Chatbots	11		Medical education	12

Note: f = occurrences

The IDs are categorized into four main groups: (i) computational intelligence, (ii) human learning, (iii) language processing, and (iv) conversational agents. Within the category of computational intelligence, terms like "artificial intelligence," "machine learning," and "deep learning" are included. Given the connection between these terms, it appears that computational intelligence encompasses the following subjects: creating intelligent machines, advancing algorithms and models facilitating computer learning, and utilizing artificial neural networks to replicate the human brain's learning process. The second classification, human learning, involves the terms "human" and "education." The extensive use of humans, which are critical participants in education, in the literature on ChatGPT suggests a strong connection between this technology and human learning processes (Eysenbach, 2023). Thirdly, "language processing" incorporates the concepts of "natural language processing,"

"language model," and "language processing." This category emphasizes analyzing and understanding human language using language models and various algorithms. In the final category of keyword plus, conversational agent technologies encompass "ChatGPT" and "chatbots." Chatbots are software applications that simulate human conversation through text or speech interactions. In contrast, ChatGPT is a specific language model that actively performs this function.

Similarly, the DEs are organized into four primary themes: (i) conversational agents, (ii) computational intelligence, (iii) language processing tools, and (iv) educational domains. The first theme, "conversational agents," consists of the same terms and concepts (ChatGPT and chatbots) as those of the IDs. Under the computational intelligence theme, the keywords include "artificial intelligence," "machine learning," and the concept of "generative AI." The terms within this theme exhibit substantial similarity to the concepts found within the "computational intelligence" theme of the IDs. Differently, "generative ai" refers to generating new content, such as text or images, using learned patterns from existing data. "Natural language processing (NLP)" and "large language models (LLM)" are involved in the category of "language processing" tools. NLP focuses on computer-human language interaction, while LLMs are AI models trained on extensive data to understand and generate human-like language. The fourth theme, "educational domains," comprises the concepts of "education," "higher education," and "medical education." Based on this finding, it can be deduced that educational research on ChatGPT particularly focuses on higher and medical education.

Overall, both the terms in IDs and the DEs share several common concepts, including artificial intelligence, natural language processing, machine learning, education, and chatbots. However, the DEs provide more specific terms, such as large language models, generative AI, higher education, and medical education, indicating a slightly narrower scope of interest than terms in the ID list. On the other hand, the ranking of the themes is different in the classification according to IDs and DEs because the concepts emphasized by the authors in the titles of the publications are different from their keywords. In other words, it is understood that although the authors frequently used such words as ChatGPT and chatbots in the keywords, they preferred to use them less in the titles of their publications.

Current Research Themes

This section explores the associations between terms and sheds light on how ChatGPT is employed within education. It first presents the findings derived from the co-occurrence network analysis and then shifts attention toward the results obtained from the thematic map analysis to understand future research directions.

Co-Occurrence Network

Keyword co-occurrence analysis is employed to uncover potential research topics with their relations and interpret the knowledge embedded within thematic clusters in the field. In this study, the IDs are utilized as the fundamental unit of analysis, as they play a pivotal role in encapsulating the primary ideas conveyed in the documents within the co-occurrence network.

The Scopus database provided 724 IDs. Synonyms were merged, and some terms were excluded for normalization before conducting the co-occurrence analysis (see Appendix). We used the default parameters of the "bibliometrix" package on the web interface "biblioshiny," namely (i) the "Walktrap" clustering algorithm with 50 keywords and (ii) a minimum of two edges. Figure 3 shows the obtained three clusters from 47 ID nodes.

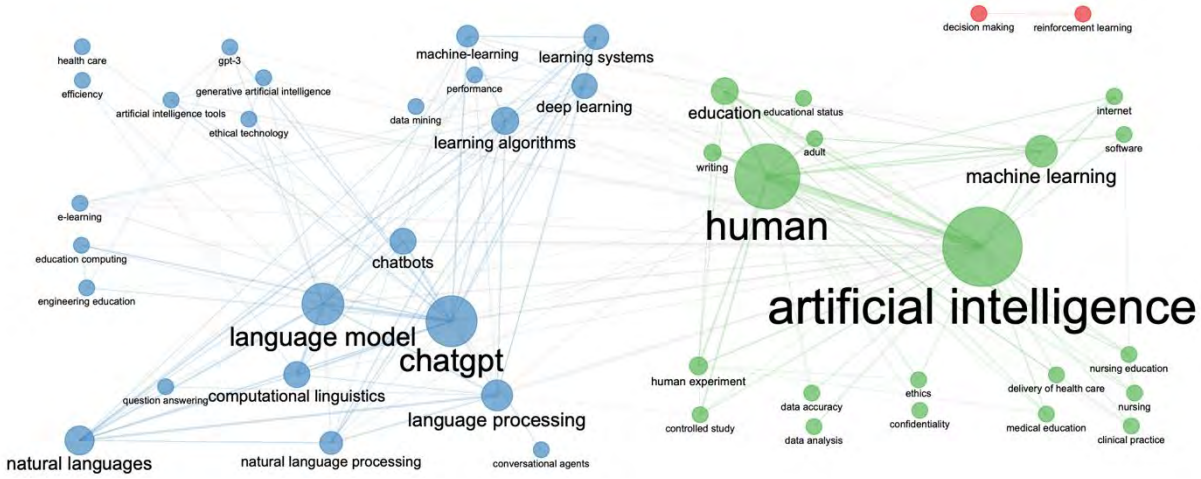

Figure 3. Keyword Plus Co-occurrence Network

Table 8. Keyword Pluses in Each Cluster

Clusters	Research stream	Nodes
Green	AI-driven healthcare and education	artificial intelligence, human, machine learning, education, software, internet, nursing, controlled study, educational status, human experiment, writing, adult, medical education, clinical practice, nursing education, confidentiality, data accuracy, data analysis, delivery of health care, ethics
Blue	Conversational AI and language processing	chatgpt, natural language processing, language model, chatbots, deep learning, language processing, natural languages, computational linguistics, learning algorithms, learning systems, education computing, machine-learning, artificial intelligence tools, e-learning, gpt-3, performance, data mining, engineering education, ethical technology, generative artificial intelligence, question answering, conversational agents, health care
Red	Intelligent decision systems	decision making, reinforcement learning

The center green node in Figure 3 corresponds to the highest occurrence of the term "artificial intelligence" in the co-occurrence network. Crucial intermediaries like "ChatGPT" and "decision making" connect the clusters. The co-occurrence relationships among the nodes determine the assignment of three research streams to each cluster, as illustrated in Table 8.

The first research stream was called "AI-driven healthcare and education." It is clear from Figure 3 and Table 8 that "artificial intelligence" is a widely covered topic in the literature of educational sciences and is connected to

several computing terms, such as "machine learning," "software," and "Internet." The term "human" with several educational terms (e.g., education and educational status) has a substantial impact on literature, specifically attracting attention to the role of AI in education. The "education" sub-term of the "human" research stream incorporates various health-related concepts such as healthcare delivery, nursing, medical education, clinical practice, nursing education, and healthcare delivery. Given the relationships among these concepts, it is apparent that ChatGPT prioritizes matters about providing healthcare services in relevant studies (Gilson et al., 2022; Jeblick et al., 2022; Sallam, 2023). Furthermore, AI can be used in research domains for controlled studies and human experiments. Ethical issues, such as confidentiality and ethics, and the data analysis process (i.e., data accuracy and analysis) are also important considerations in using AI in research.

The second research stream, the blue cluster, was named "conversational AI and language processing," which encompasses different aspects of conversational AI. ChatGPT, a conversational AI system and a particular type of chatbot, occupies a central position within the co-occurrence network, covering other important elements. This term is closely associated and often used with language processing terms. Essentially, it implies the proficiency of ChatGPT in executing various language-related tasks such as comprehending and manipulating human language (i.e., natural language processing), producing or comprehending text that resembles human communication (i.e., language models), and providing responses to user inquiries or questions (i.e., question answering). Machine learning and learning systems are other focus areas within this research stream. These concepts play a crucial role in shaping the design of conversational AI systems and contain neural networks consisting of multiple layers (e.g., deep learning). They are utilized to train machine learning models, enhance their efficacy (e.g., learning algorithms, learning systems), and facilitate extracting valuable information or patterns from extensive datasets (e.g., data mining).

In addition, the second research stream also places a considerable emphasis on artificial intelligence. It includes terms like "artificial intelligence tools," "generative artificial intelligence," and "GPT-3" to address this domain. These concepts primarily revolve around generating contextual data, such as text, images, or music. The connections between ChatGPT and these terms highlight that ChatGPT serves as an artificial intelligence tool built upon generative AI, particularly leveraging the capabilities of GPT-3. The intersection of conversational AI and education reveals a notable association between ChatGPT and domains such as "e-learning," "engineering education," and "educational computing." Existing literature may suggest that ChatGPT plays a pivotal role in addressing the needs of online education, engineering education, and other educational areas where technology integration is crucial (Francisco & de Oliveira Silva, 2022; Ouyang et al., 2022). Furthermore, the second research stream addresses important aspects concerning "healthcare" and "efficiency." Establishing direct connections between these terms and other focal points can be challenging. Nevertheless, they might be a valuable indicator of the effectiveness of conversational AI, particularly in the realm of ChatGPT applications within healthcare services.

The third research stream, the red cluster, represents the "intelligent decision systems" indicating that ChatGPT can be utilized in decision-making processes and reinforcement learning (Liu et al., 2023). For instance, ChatGPT can offer valuable information and recommendations tailored to users' preferences (Cotton et al., 2023).

Furthermore, it may also be employed in reinforcement learning scenarios (Mhlanga, 2023; Rudolph et al., 2023).

Thematic Map

The researchers used thematic map analysis with IDs to examine the prevalence of different themes and reveal issues that require further research in the literature on ChatGPT in education. The following parameters were employed: (i) limiting the analysis to 250 words, (ii) establishing a minimum frequency of 5 occurrences for each cluster, (iii) requiring three labeled terms for each cluster, and (iv) implementing the "walktrap clustering algorithm" as proposed by Lancichinetti and Fortunato (2009). The thematic maps consist of two dimensions: centrality (x-axis) and density (y-axis). Centrality indicates the importance of a theme, while density reflects its level of development (Cobo et al., 2011). Figure 4 shows a comprehensive overview of the field's thematic landscape, allowing the identification of different types of themes and their positions within the research domain based on centrality and density.

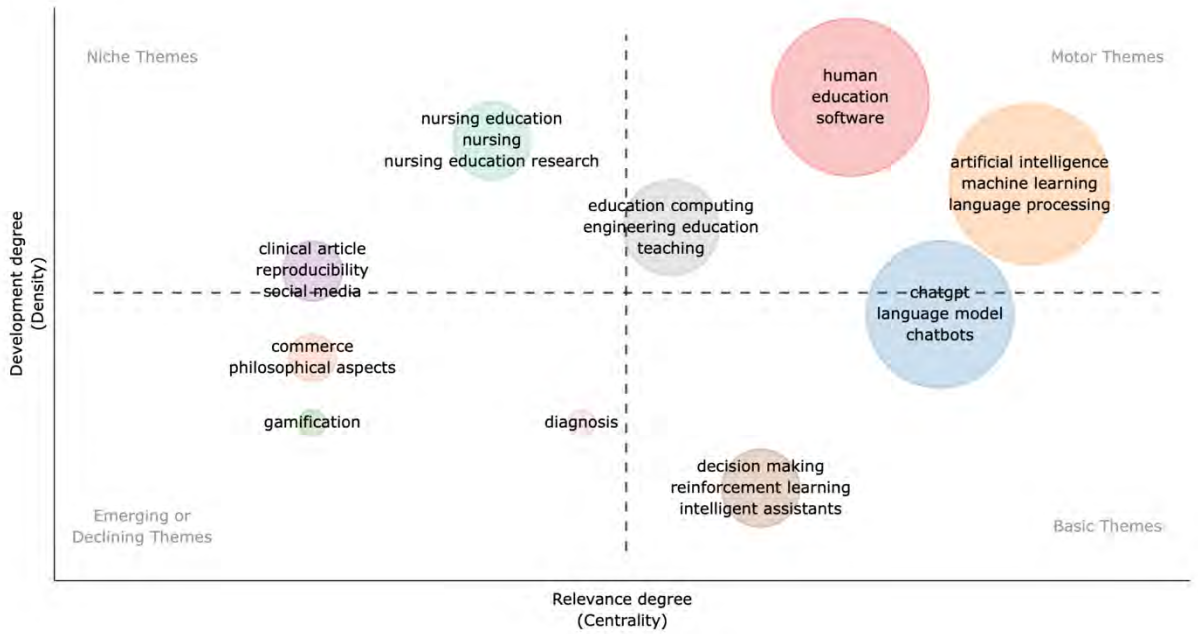

Figure 4. The Thematic Map of IDs.

Figure 4 consists of four quadrants: i) motor, ii) basic, iii) niche, and iv) emerging themes. Motor themes play a central role in the research landscape as they are both important and well-developed. Niche themes, although well-developed, have limited overall significance in the research context. Emerging themes are characterized by their isolated nature and relatively weak development, whereas basic themes are important in the field but require further development to reach their full potential. Table 9 provides more details about IDs in all themes.

This research classifies IDs under three motors, two basics, two niches, and three emerging themes. The first research stream, "intelligent systems and learning technologies," under the motor themes category, primarily explores the theoretical and practical aspects of intelligent systems. Involved in the same theme, the second research stream, "human-centered learning and practice," covers various areas that emphasize the crucial role of

humans in education, technology, and healthcare (Arif et al., 2023; Huang et al., 2023; Gilson et al., 2022) and how these domains intersect to enhance learning and practical applications across different fields. A considerable amount of research related to ChatGPT has been conducted within this theme, underscoring its importance in the field. Another research stream in the motor theme, "computational education and learning," explores the intersection of education with computing-related disciplines like computer science education and engineering education. The concepts within this research stream are vital to the literature and are well-developed. However, its presence in the literature is relatively less dense than the other motor themes.

Table 9. Themes and IDs in the Thematic Map

Theme	Research stream	IDs in clusters
Motor	Intelligent systems and learning technologies	Artificial intelligence, machine learning, language processing, natural languages, learning algorithms, learning systems, deep learning, natural language processing, e-learning
	Human-centered learning and practice	Human, education, software, internet, controlled study, human experiment, writing, adult, medical education, clinical practice
	Computational education and learning	Education computing, engineering education, teaching, computer science education, introductory course, learn
Basic	Conversational AI	Chatgpt, language model, chatbots, computational linguistics, artificial intelligence tools, gpt-3, generative artificial intelligence, ethical technology, conversational agents, high education
	Intelligent decision support systems	Decision-making, reinforcement learning, intelligent assistants
Niche	Nursing education and research	Nursing education, nursing, nursing education research, nursing student
	Clinical research and communication	Clinical article, reproducibility, social media
Emerging	Philosophy of commerce	Commerce, philosophical aspects
	Gamification	Gamification
	Diagnosis	Diagnosis

The research stream "Conversational AI" primarily falls under the basic themes category, with only a small portion belonging to the motor themes. This stream explores various aspects of conversational AI, encompassing artificial intelligence and language processing, including language models like GPT-3, chatbots, and conversational agents. While the concepts within this research stream are highly relevant to the field, they require additional investigation, particularly in educational settings. Another research stream, "intelligent decision support systems," under the basic theme, includes the concepts of "decision making," "reinforcement learning," and "intelligent assistants." These concepts are quite significant for ChatGPT-oriented educational research. However, as seen in Figure 4, further research is required to uncover their full potential.

The niche theme in the analysis of the thematic map consists of two research streams: "nursing education and research" and "clinical research and communication." The former delves into different aspects of nursing education, including the specific field of nursing education research, while the latter focuses on clinical articles, reproducibility, and the impact of social media in the field. Figure 4 demonstrates that both research streams have undergone substantial development, indicating the involvement of numerous researchers in exploring these topics. However, their relevance to ChatGPT-oriented educational literature still needs to be improved.

Lastly, the thematic map analysis uncovered three emerging themes: "philosophy of commerce," "gamification," and "diagnosis." These themes display a limited number of IDs compared to others, suggesting they are not yet fully developed or mature. Furthermore, they appear relatively disconnected from ChatGPT-oriented works. Consequently, there is a clear need for further studies that concentrate on these emerging themes, with a specific emphasis on exploring the role of ChatGPT in educational contexts (Huang et al., 2023; Kuhail et al., 2023; Wu & Yu, 2023; Zhang et al., 2023). By delving deeper into these themes and examining their relationships with ChatGPT, researchers can contribute to advancing and understanding the potential applications and impacts of ChatGPT in education.

Conclusions and Suggestions

Recognizing the valuable insights that review studies can offer into the efficacy and influence of a research topic and providing suggestions for future research, this study was conducted to analyze research on ChatGPT in education within the Scopus database. It is important to note that the study is confined to the selected Scopus database, and its findings are contingent upon the accuracy of the metadata within that database.

Regarding the first research question, descriptive statistics of 212 studies published in the 2022-2023 period reveal that the studies are mostly research articles and multi-authored and that the number of calculated keyword plus (ID) is more than that of the author's keywords. For the second research question, The JMIR Medical Education, Journal of Applied Learning and Teaching, and Journal of University Teaching and Learning Practice are the three most influential sources in this field. Furthermore, studies primarily come from the subject of medical education. Most research concentrates on the benefits and drawbacks of using ChatGPT in education. The findings also show that ChatGPT research in education is still in its early stages, with common characteristics across influential writers. In addition, it is pointed out that the United States and the United Kingdom have a leading status in production and citation impact. Despite fewer publications, countries like Belgium, Korea, and Canada rank high in citations. The dominant roles of the USA, Australia, and China among corresponding authors are also figured out in this study. All these findings show ChatGPT's expanding position in education and its global contributions.

In line with the third research question, the top ten core terms of research on ChatGPT in education, depending on both keyword plus (ID) and author's keywords (DE), are revealed. Then, those IDs are classified under the following four groups: (i) computational intelligence, (ii) human learning, (iii) language processing, and (iv) conversational agents. Likewise, the DEs are also classified under the following four primary themes: (i) conversational agent technologies, (ii) computational intelligence, (iii) language processing tools, and (iv)

educational domains. The four most frequently used ID keywords are "Artificial intelligence," "Human," "ChatGPT," and "Natural language processing," respectively. Similarly, the four most common DE keywords are "ChatGPT," "Artificial intelligence," "Large language models," and "Chatbots." The last research question has contributed to the literature by revealing two forefront research subjects: (i) AI-driven healthcare and education and (ii) Conversational AI and language processing. In addition, the thematic map illustrated in this study may help researchers better understand the emerging themes and gaps that require more research on ChatGPT in education, including but not limited to the "philosophy of commerce," "gamification," and "diagnosis."

Conclusions from this study offer valuable insights into the research landscape of ChatGPT in education. However, a few suggestions should be made to improve the overall understanding of these findings. While this study was conducted using the Scopus database, future research might broaden the analysis to other reputable databases to guarantee a more thorough representation of the subject. Given the reliance on Scopus metadata, further studies may involve cross-referencing with other databases or sources to validate the accuracy and completeness of metadata, ensuring a robust foundation for analysis. Furthermore, extending the study over several years might show changing trends and dynamics in the field, allowing for a more detailed view of its growth trajectory and prospective adjustments. In addition to the quantitative findings, qualitative studies provide in-depth insights into the motivations, challenges, and experiences of researchers and educators utilizing ChatGPT in educational contexts. Lastly, a full knowledge of ChatGPT's revolutionary potential might be gained by assessing its long-term influence on educational practices, student learning outcomes, and pedagogical approaches. By addressing these recommendations, researchers may strengthen the study's basis and contribute to a more comprehensive and nuanced understanding of ChatGPT's role in shaping the future of education.

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Appendix. List of Removed or Merged Terms

keyword plus	
Removed nodes	● Article, Language, Students, 'current, ecosystem, codes (symbols), information source, follow up, male, knowledge, stochastic systems, optimization, counterfactuals, signal encoding
Synonym nodes	● artificial intelligence, artificial intelligence (ai), ai ● large language models, large language model, large language model (llm) ● natural language processing, natural language processing (nlp), natural language processing systems ● chatbots, chatbot ● open ai, openai ● gpt, generative pre-trained transformer ● conversational agents, conversational agent ● educational technology, educational technologies ● human, humans ● generative artificial intelligence, generative ai ● reinforcement learning, reinforcement learnings ● ontology, ontology's ● decision making, decisions makings
authors keyword	
Synonym nodes	● artificial intelligence, artificial intelligence (ai), ai ● large language models, large language model, large language model (llm) ● natural language processing, natural language processing (nlp), natural language processing systems, nlp ● chatbots, chatbot ● open ai, openai ● gpt, generative pre-trained transformer ● generative artificial intelligence, generative ai