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ChatGPT: a bibliometric analysis and visualization of emerging educational trends, challenges, and applications

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ABSTRACT

This study conducts a comprehensive bibliometric analysis and visual exploration of the chat generative pre-trained transformer (ChatGPT) literature in 2023, focusing on its trends, challenges, and applications in education. Using RStudio for bibliometric analysis and VOS viewer for data visualization, this study examines publications from the Scopus database. Following the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines, the systematic review process reinforces the robustness of the analysis. The finding reveals notable trends in the utilization of ChatGPT. Key insights underscore ChatGPT's increasing role in enhancing engagement, facilitating personalized learning, and fostering student creativity and critical thinking. However, its integration into education encounters obstacles, including ethical considerations, issues of academic honesty, and the imperative for precise usage guidelines; notable applications of ChatGPT encompass language learning, tutoring, automated feedback provision, and functioning as a virtual assistant. These applications showcase ChatGPT's potential to reshape the educational landscape by introducing innovative pedagogical methods and enriching the student experience. This combined bibliometric and visual analysis provides a comprehensive view of the current status of ChatGPT within the educational domain. It provides a snapshot of the role of ChatGPT in education, offering valuable insights for future research endeavors.

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1. INTRODUCTION

Rapid advancements in technology have profoundly reshaped the educational landscape [1]. Emerging technologies such as blockchain technology [2], artificial intelligence (AI), and virtual reality (VR) have instigated sweeping challenges [3], [4]. AI, represented by models such as ChatGPT, has paved the way for novel prospects in personalized learning, automated grading, and intelligent tutoring systems [5]. These innovations do not exist in isolation but rather form an intricate web, fundamentally altering the dynamics of teaching and learning in the digital era.

Chat generative pre-trained transformer (ChatGPT) is an advanced language model with a natural language processing (NLP) ability capable of generating human-like text responses [6]. The AI-based chatbot was explicitly crafted for the purpose of facilitating seamless and contextually relevant conversations [7].

ChatGPT was publicly launched on November 30, 2022, by OpenAI, based in San Francisco [8]. The generative pre-training transformer (GPT 3.5) [9] has quickly gained popularity. By January 2023, it had become the fastest-growing consumer software application in history (at that time), with more than 100 million users [10]. The Threads App by Meta is now faster [11]. OpenAI expanded its capabilities further by launching Generative Pre-trained Transformers 4 (GPT-4). GPT-4, released on March 14, 2023, is available via API and premium ChatGPT users. Within months, Google, Baidu, and Meta accelerated the development of their competing products: Bard, Ernie Bot, and LlaMA [12]. Elon Musk has announced that xAI, his new AI-focused company, intends to understand "the true nature of the universe" [13]. In May 2023, OpenAI launched an iOS application for ChatGPT. The app supports chat history synchronization and voice input (using Whisper, OpenAI's speech recognition model) [14].

Recent review articles emphasize the wealth of research conducted on ChatGPT across various fields, with studies demonstrating its extensive usage in academic writing, essays, poetry, stories, computer programs, technical writing, and other forms of text production [15], [16]. Salvagno *et al.* [17] believes it would be more appropriate to encourage teachers and students to incorporate AI tools, such as ChatGPT, into the writing process rather than impose restrictions [18]. Meanwhile, Grassini [19] argued that students and educators should receive education about the use of AI tools, as these tools are likely to gain increasing importance in future work environments. Some researchers have integrated the ChatGPT into their research processes [20], [21]. The capacity of ChatGPTs to generate original content has also raised ethical inquiries within academic circles [22]–[26].

Because of the software's propensity to provide false or misleading information, also referred to as AI hallucinations [27], researchers have reservations about placing sole reliance on ChatGPT-generated outputs [28]. Certain observers have articulated apprehensions regarding ChatGPT's capacity to displace or erode human intelligence and its potential to facilitate plagiarism or propagate misinformation [29]. According to OpenAI guest researcher, the organization is actively developing a tool to generate watermark text generation systems digitally. This initiative aimed to counteract malevolent actors who might exploit their services for academic plagiarism or spam.

The present study aims to provide valuable insights into the current ChatGPT-related research, enabling educators to make informed decisions about its implementation. This study explores the trends, applications, and use of ChatGPT in education. This study highlights the potential benefits of ChatGPT for educators in improving learning and teaching outcomes. Addressing these challenges to reduce risks and promote ethical practices when using ChatGPT in educational settings is essential. This study contributes to the literature on ChatGPT by providing a comprehensive bibliometric analysis and visual presentation. These analyses help consolidate the knowledge of ChatGPT and identify research gaps. This research offers an exploratory but potentially relevant foundation for future studies and allows researchers to explore specific aspects of the ChatGPT in education.

2. METHOD

To ensure the validity of our study, we began with a rigorous literature review. This stage plays a vital role in our technique since it enabled us to understand recent seminal studies on ChatGPT in education thoroughly. By studying the existing literature, we uncovered gaps and nuances in the current body of knowledge and laid a solid framework for our investigation.

This study used a comprehensive bibliometric and visual analysis methodology integrated with the PRISMA technique to examine the literature on ChatGPT in education. PRISMA is a widely recognized and recommended tool for conducting systematic reviews [30], [31]. This research procedure is structured into four key stages: i) searching for relevant literature; ii) screening identified articles; iii) conducting a detailed analysis; and iv) visualizing the findings, as illustrated in Figure 1. By adopting this systematic approach, the study aims to provide a thorough understanding of the current landscape and trends in the utilization of ChatGPT within educational contexts. This multifaceted methodology ensures a rigorous examination of the available literature, contributing to the robustness and reliability of the study's findings.

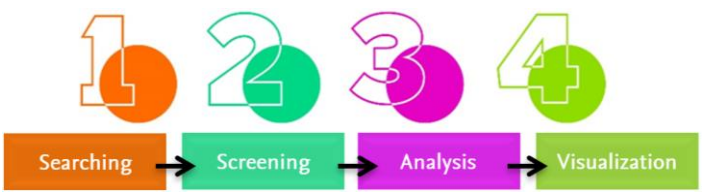

Figure 1. Research procedure

This study was initiated by systematically searching the Scopus database and compiling an exhaustive selection of relevant publications. Subsequently, we subjected the collected data to a meticulous screening process to ensure precision and eliminate any redundancy or duplication. To perform a robust bibliometric analysis, we leveraged R Studio, a widely recognized statistical software package [32], [33]. This bibliometric investigation yielded valuable insights into the research landscape concerning ChatGPT within the realm of education.

The finding was visualized using VOSviewer, a specialized software tool for constructing bibliometric networks [34]. This enabled us to generate visual representations, including co-authorship, co-citation, and keyword co-occurrence maps [35]. In this study, we analyzed and interpreted the collected data and visualizations to identify the trends, challenges, and applications of ChatGPT in the education domain.

During the search process, we applied the following criteria: (TITLE-ABS-KEY ("ChatGPT") AND TITLE-ABS-KEY ("Education")) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (LANGUAGE, "English")). Based on the titles, abstracts, and keywords containing the terms "ChatGPT" and "Education," the documents were restricted to journal articles only, written in English, and within the year 2023. Subsequently, we conducted an in-depth review to ensure the relevance of the articles selected for the analysis. This review commenced with an initial examination of the abstracts, through which we omitted any discussions unrelated to the ChatGPT in education from our dataset. This additional step assisted us in fine-tuning the dataset, ensuring that we exclusively incorporated articles that directly addressed the subject matter in our analysis.

3. RESULTS AND DISCUSSION

The researchers successfully identified 93 articles that met the criteria. These articles comprised journal publications from 2023, a choice based on ChatGPT's public release towards the end of 2022. Notably, our search was conducted on June 10, 2023. Consequently, it is possible that some publications from the latter half of 2023 will not be included in our findings. Despite this limitation, the identified articles provide valuable insights into the usage and trends of ChatGPT in education. We also attempted to search for articles from 2022; however, we did not find any instances of ChatGPT use in the education context during that timeframe unless the keyword "education" was not utilized in those articles. Therefore, our primary focus is on articles published in 2023.

The search results were exported and compiled into a comma-separated value (CSV) format, creating a foundation dataset for subsequent analysis. In the initial analysis stage, we scrutinized the metadata of the dataset for completeness, which is a crucial aspect of conducting rigorous bibliometric research. Complete metadata encompasses vital details such as article titles, authors, journal publications, publication years, abstracts, and keywords. This comprehensive metadata facilitates precise data selection and filtering based on research criteria. Researchers can efficiently and accurately search for and gather pertinent data with rich metadata. Information availability, including titles and abstracts, aids researchers in assessing the relevance of articles to a research topic. Ensuring metadata completeness is pivotal for a thorough and valid bibliometric analysis. Table 1 presents the full scope of the metadata within the acquired dataset.

Table 1. Completeness of bibliographic metadata

Metadata	Description	Missing counts	Missing %	Status
AB	Abstract	0	0.00	Excellent
AU	Author	0	0.00	Excellent
DT	Document type	0	0.00	Excellent
SO	Journal	0	0.00	Excellent
LA	Language	0	0.00	Excellent
PY	Publication year	0	0.00	Excellent
TI	Title	0	0.00	Excellent
TC	Total citation	0	0.00	Excellent
C1	Affiliation	1	1.08	Good
DI	DOI	2	2.15	Good
CR	Cited references	5	5.38	Good
DE	Keywords	7	7.53	Good
RP	Corresponding author	15	16.13	Acceptable
ID	Keywords plus	65	69.89	Critical
NR	Number of cited references	93	100.00	Completely missing
WC	Science categories	93	100.00	Completely missing

Upon evaluating the provided data, bibliometric analysis indicates that the majority of metadata attributes demonstrate a high level of completeness. However, a few specific attributes exhibited varying degrees of missing data. It is important to highlight that the attributes "Keywords Plus," "Number of Cited References," and "Science Categories" did not yield satisfactory results and were consequently omitted from the analysis. This discrepancy arises from the fact that Scopus does not provide information for the "Keywords Plus" category, which is available in other databases such as WoS. As a result, three metadata were excluded from the analysis. We retained a dataset consisting of 93 articles obtained from the study for further processing and analysis in subsequent stages.

3.1. Main information

The dataset comprises 93 documents from 64 journal references. During the analysis stage, we delved deeper into the dataset and generated visualizations across various categories to gain a more comprehensive understanding of the research landscape. Initially, we identified the relevant sources and authors, highlighting their significance within their respective fields. Subsequently, Bradford's law [36] was employed to pinpoint the core sources that contributed substantially to our dataset, thereby providing more clarity regarding the concentration of relevant information. Furthermore, we assessed authors' productivity by tracking their output and monitored the production of research papers by affiliations over time, tracking changes in their work and exploring the scientific results of different countries, noting variations in their contributions.

Finally, we identify the top countries and documents that received the highest citations from scholars worldwide, demonstrating their influence and impact within scholarly communities. As part of our data analysis, we investigated the most frequently occurring words and emerging topics within our dataset, providing insights into critical themes and evolving areas of study. Subsequently, we constructed a co-occurrence network to reveal the relationships and connections between various terms and concepts. Through our analysis and presented visualizations, our objective was to explore the dataset exhaustively, identify crucial trends and patterns, and facilitate deeper comprehension of the research landscape within each discipline.

3.2. Most relevant sources

Figure 2 shows the distribution of articles among different sources or journals. The data illustrates the number of articles extracted from each source within the dataset. The Journal of Applied Learning and Teaching emerged as the most prominent source, contributing nine articles to the final dataset.

The Journal of University Teaching and Learning Practice closely follows five articles. Sustainability is another notable source of the four articles. JMIR Medical Education, Applied Sciences, Computers, and Education: Artificial Intelligence, Contemporary Educational Technology, Eurasia Journal of Mathematics, Science and Technology Education, International Journal of Educational Technology in Higher Education, and International Journal of Management Education contributed two articles to the dataset.

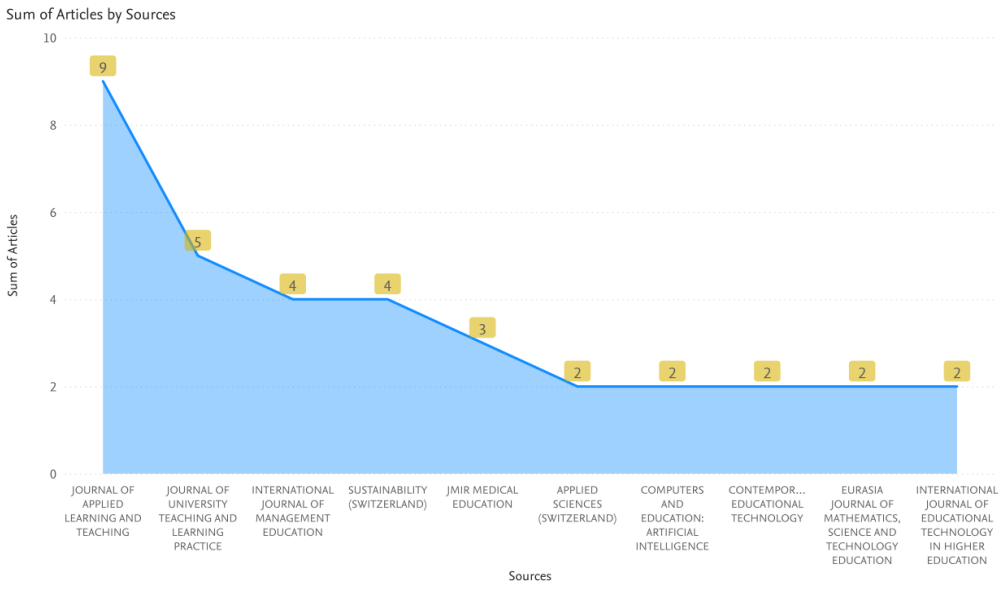

Figure 2. Most relevant sources

3.3. Most relevant authors

Figure 3 plays a pivotal role in unveiling the leading contributors within the realm of ChatGPT in education. This visualization highlights the top 10 authors who have made significant strides in this domain, as evidenced by the number of articles attributed to each. The data encapsulated in Figure 3 not only presents the names of these influential authors but also provides a quantitative measure by specifying the exact count of articles they have authored. Additionally, fractionalized values accompany each author, offering insights into the proportion of their contributions within the broader dataset. This meticulous breakdown enhances our understanding of the individual impact of each author within the landscape of ChatGPT research in education.

It is important to note that these findings can change and vary significantly due to factors such as the quality of metadata, data sources, the range of years covered, and the specific dataset used. Additionally, there is a possibility of identical author names representing different individuals. Therefore, it is crucial to exercise caution and consider these potential biases.

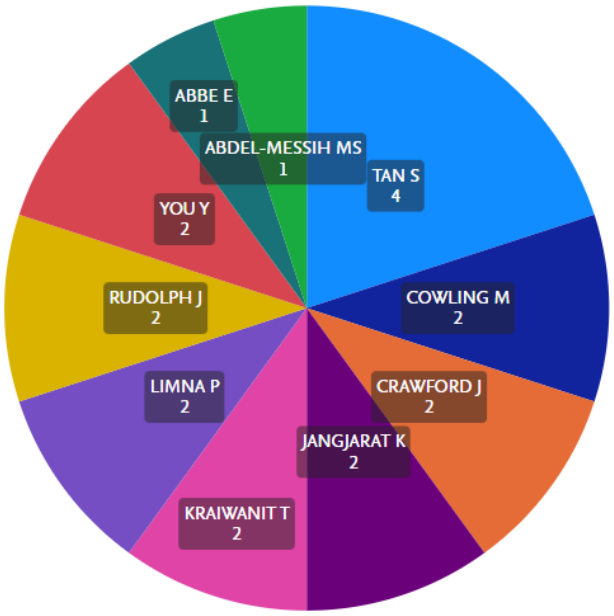

Figure 3. Most relevant authors

3.4. Core source by Bradford's law

In Zone 1, journal analysis revealed crucial insights into trends and focal areas within the field. We concentrated on journals that substantially contributed to the existing literature during the period under consideration for analysis. This approach enabled us to understand the research areas that exhibited notable activities. As a part of our analysis, we identified several journals with high frequencies in Zone 1. These include the Journal of Applied Learning and Teaching, Journal of University Teaching and Learning Practice Sustainability, JMIR Medical Education, Applied Sciences, and Computers and Education: Artificial Intelligence, Contemporary Educational Technology, The Eurasia Journal of Mathematics Science Technology Education, and the International Journal of Educational Technology Higher Education. These publications proved influential and attracted many authors and readers, as seen in Figure 4.

3.5. Affiliations production over time

We noted different levels of research output among various affiliations and institutions. Charles Sturt University emerged as the most prolific contributor, with nine published articles underscoring our institution's active involvement in research activities during the specified year. On the other hand, the Australian Institute of Business (AIB), Rangsit University, and Yale University School of Medicine each published seven articles. This indicates that similar to these institutions, we have made significant research contributions, emphasizing our commitment to advancing knowledge and scholarly output in our respective fields, as shown in Figure 5.

Similarly, Swansea University and the University Hospital of Lausanne published six articles in 2023, showcasing our institutions' dedication to conducting and sharing research. It is important to emphasize that the number of articles alone does not necessarily reflect the quality or impact of the research. These numbers indicate only a quantitative measure of institutions' research productivity.

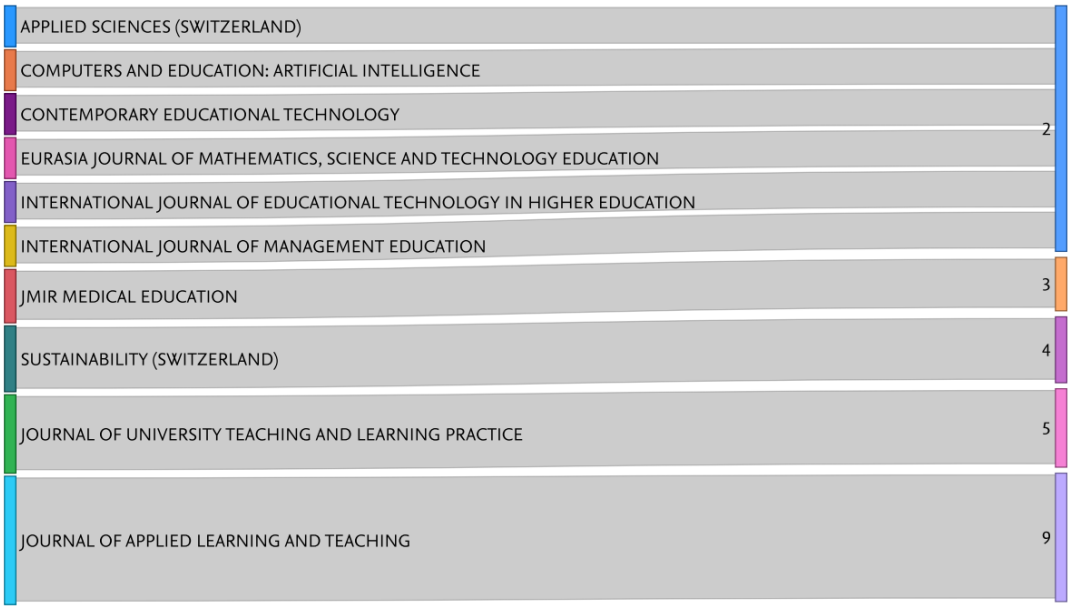

Figure 4. Core source by Bradford's law

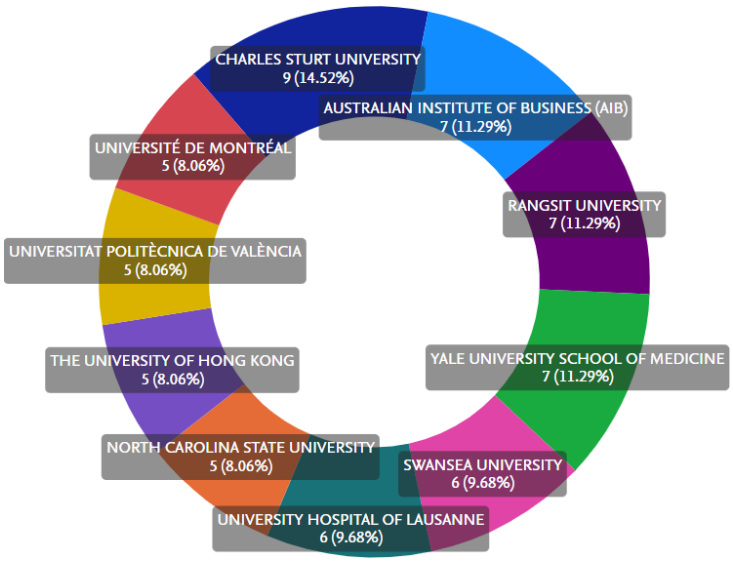

Figure 5. Affiliations production over time

3.6. Most cited countries

The data presented in Figure 6 provide information on the total number of citations (TC) and average number of citations per article for various countries. Among these nations, the United States (USA) has the highest total citation count, accumulating 128 citations. On average, each article that originated from the USA received 7.50 citations, underscoring the substantial impact and recognition of research published by authors in the United States. Following the USA, the United Kingdom (UK) achieved a total citation count of 66, with an average of 16.50 citations per article. This average significantly exceeds that of the USA, suggesting that research articles from the UK tend to receive more scholarly attention and recognition.

Italy garnered a total citation count of 29, with an average of 14.50 citations per article. These findings indicate that despite a moderate citation rate, research articles from Italy have a relatively high average number of citations per article, as shown in Figures 6 and 7.

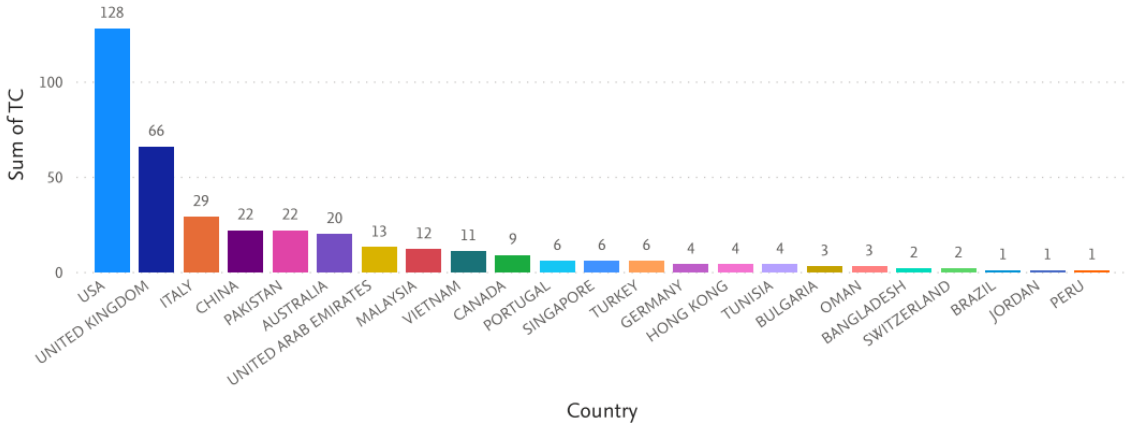

Figure 6. The most cited countries

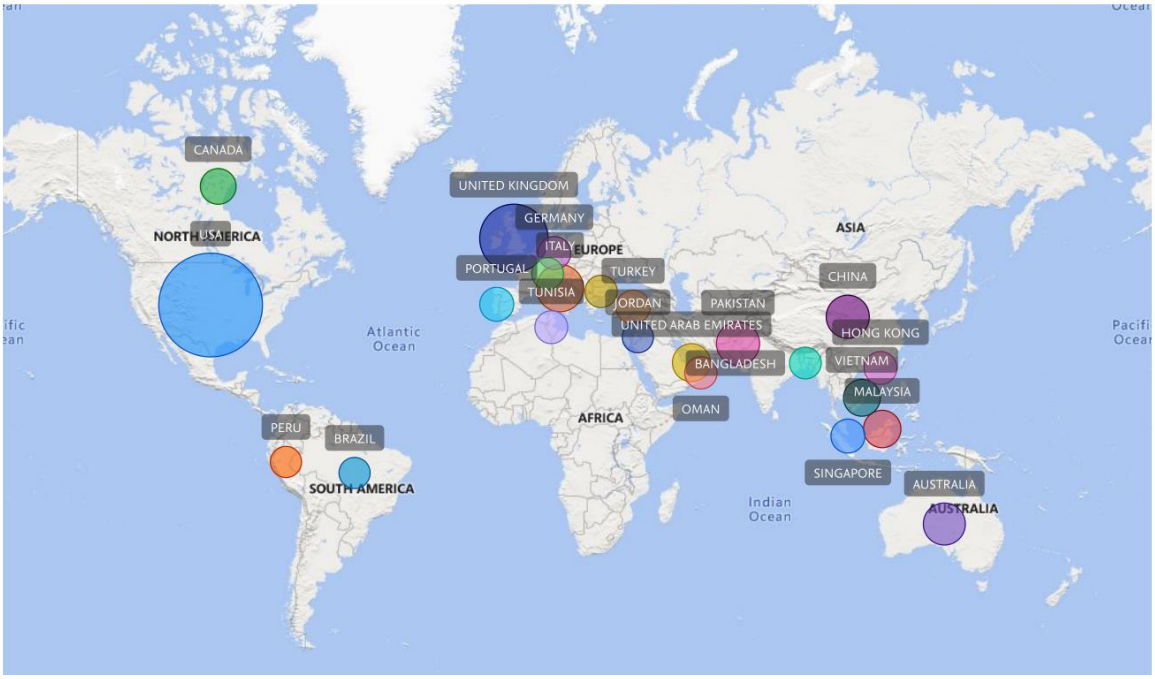

Figure 7. Countries map of the most cited article

Data from China and Pakistan reveal that both countries have the same total citation count, with 22 citations each, as seen in Figure 6. However, there was a significant contrast in the average number of article citations. China boasts an average of 7.30 citations per article, whereas Pakistan records an average of 22.00 citations per article. This suggests that research articles from Pakistan tend to have a higher impact and receive more citations on average than those from China. However, Australia has accumulated a total citation count of 20, with an average of 2.50 citations per article. A lower average citation count indicates a relatively low impact or recognition of research articles from Australia. The United Arab Emirates, Malaysia, Vietnam, Canada, Portugal, Singapore, and Turkey exhibited varying total citation counts ranging from 6 to 13. The average number of citations per article varies in these countries. These data may imply that countries with higher research output are more advanced in AI-driven digitalization or that in such countries, AI tools have

been more widely implemented in private or professional life. Additionally, these data could indicate which countries have made more significant investments in AI research, possess better research facilities, or maintain a more focused research approach, particularly for emerging technologies.

3.7. Most globally cited documents

This dataset encompasses a list of papers published in 2023 and their total citation counts, which measure their impact and recognition within academic communities, as seen in Table 2. The citation counts associated with the top articles signify their influence and significance in their respective fields. Gilson's paper receives the highest number of citations, closely followed by Dwivedi and Rudolph with substantial counts. Pavlik *et al.* [24] have contributed significantly to their respective research areas, garnering considerable interest and citations from scholars worldwide. Furthermore, these papers may have addressed significant research questions or offered valuable insights widely recognized and acknowledged by other researchers, thus justifying their citations. In this high-impact document (based on citation count), we reviewed the findings from various research studies regarding ChatGPT, its challenges, and applications. Based on our comprehensive review of previous research, ChatGPT has indeed emerged as a highly impactful technology in education. To provide a more comprehensive summary, we present our findings.

The recent surge in ChatGPT's popularity underscores the significance of simple, user-friendly interfaces as a significant contributing factor to its widespread adoption [37]. Gilson *et al.* [38] research highlights ChatGPT's strong performance and ability to provide logical answers to medical examination questions, making it an indispensable tool in medical education. Dwivedi's research confirms the effectiveness of ChatGPT in increasing productivity and shows significant potential benefits across industries such as banking, hospitality, tourism, and information technology [39]. However, before undertaking such endeavors, it is essential to consider the ethical and legal challenges. Rudolph has also identified some of these risks, which encompasses threats to privacy and security [40], potential biases, misuse, and the dissemination of misinformation [41]–[44]. ChatGPT stands out as an advanced chatbot capable of producing impressive text within seconds, a finding corroborated by Rudolph *et al.* [40]. This study contributes to understanding the benefits and challenges of using artificial intelligence chatbots in teaching, learning, and assessment practices.

While language models built on artificial intelligence, such as ChatGPT, have shown impressive capabilities, their real-world performance in fields such as medicine, which demand high-level and intricate reasoning, still needs to be thoroughly assessed [45], [46]. Furthermore, while the ChatGPT promises to deliver potential benefits by generating scientific articles or other scholarly outputs for publication, it is imperative to acknowledge and address substantial ethical concerns [47], [48]. Despite its advantages and challenges, ChatGPT has distinctive drawbacks.

Importantly, several studies [49] have discussed ChatGPT's susceptibility to "hallucination" phenomena, wherein it generates answers that may appear plausible but are potentially inaccurate or nonsensical. Furthermore, ChatGPT can reinforce any bias in the training data, which may influence the generated outputs and perspectives. There is also a risk of ChatGPT being misused for plagiarism and academic integrity violations, potentially leading to a decline in critical thinking skills among students who rely excessively on it, resulting in educational imbalances. Addressing these concerns requires a multipronged approach. This includes ongoing research to improve AI models, educate users about their limitations, foster responsible use, and promote a balanced approach to learning that combines AI assistance with independent thinking and exploration.

Although we recognize that ChatGPT can be an invaluable educational tool, its usage must be approached with caution, and additional guidelines for its safe implementation in education must be developed [50]. Avoiding ChatGPT is not a solution, as the technology is intended to enhance human work. However, in education, it is crucial to promote vocational values and character education and enhance digital literacy to ensure responsible utilization [51]. This technology is a double-edged sword that offers benefits but also has the potential for severe ethical violations when misused [52]–[54].

Universities should promptly establish training programs to educate educators, instructors, and students on the proper utilization of ChatGPT [55]. ChatGPT can serve as a powerful tool for encouraging creativity and innovation in learning by conducting comparative studies between student responses and ChatGPT in reflective learning activities. Students engaging in ChatGPT should develop critical thinking skills that enable them to assess information and generate novel ideas critically.

Therefore, academics must adapt their teaching and assessment methodologies in response to the increased availability of AI in society. Although various public debates and university responses have primarily focused on concerns regarding academic integrity and potential assessment design innovations using ChatGPT for academic work [56], Iskender research [57] indicates that ChatGPT cannot replace human creativity because of the lack of authenticity and novelty in its output. Consequently, the following question arises: should ChatGPT be blocked or banned in educational institutions? Blocking or restricting ChatGPT in

educational settings does not provide a comprehensive solution to the prevailing challenges, similar to social media, where access is still possible whenever and wherever there is an internet connection. Thus, the approach to AI tools such as ChatGPT in education should involve a combination of restrictions and a concerted effort to educate users about responsible and effective use [58], [59].

Currently, educators have the opportunity to take several strategic measures to mitigate the potential risks and negative consequences associated with the ChatGPT. First, educators should consider implementing innovative assessment methods, such as active conversational learning or oral examinations, to gauge students' skills. This approach creates an environment conducive to refining verbal communication skills, with the potential future support of voice recognition technology, and aligns with the evolving landscape as ChatGPT becomes more prevalent [60].

By synergizing human expertise with ChatGPT's capabilities, educators can strike a balance between both strengths. This entails utilizing ChatGPT as a supplementary tool in teaching and learning processes while fostering students' critical thinking and problem-solving abilities [61]. Continuous monitoring and evaluation of ChatGPT integration are imperative to ensure that ethical standards are maintained and to facilitate the comprehensive development of students [62].

Table 2. Most globally cited documents

Paper	Total citations
Gilson [38]	62
Dwivedi [39]	54
Rudolph [40]	44
Pavlik [24]	44
Cascella [52]	27
Huh [25]	25
Tlili [6]	22
Khan [63]	22
Crawford [12]	13
Lim [44]	12
Perkins [61]	11
Halaweh [64]	10
Sun [45]	9
Sullivan [62]	9
Hallsworth [46]	9
Iskender [57]	7
Kooli [28]	7
Rudolph [26]	7
Sng [43]	6
Abdel-Messih [47]	6
Firat [48]	6
Cooper [49]	5
Xames [41]	4
Choi [42]	4

3.8. Most frequent words

The research examined the prevalent keywords used in research concerning the integration of ChatGPT in educational contexts. In bibliometric analysis, these frequently employed words hold significance, shedding light on their prominence and popularity within a specific research domain [65]. Collectively, these terms provide an overview of prevailing trends, research focal points, and extensively explored subjects in the academic literature. The analysis highlighted numerous frequently cited keywords in ChatGPT's educational applications. Notably, several keywords surfaced prominently, as shown in Figure 8.

Firstly, the term "ChatGPT" appeared 65 times in our dataset, highlighting the prominence of ChatGPT as a recognized brand associated with an artificial intelligence system or model. This finding indicates the significance of the ChatGPT in educational research and its recognition within the academic community. Second, "artificial intelligence" was mentioned 48 times, underscoring its central position and relevance in advancing technology. AI has gained significant attention across various disciplines, including education, owing to its potential to transform learning environments and improve educational outcomes [64].

The keyword "education" was referenced 18 times, indicating its specific focus in the research on ChatGPT. This finding suggests that researchers have shown significant interest in exploring the applications, implications, and potential benefits of integrating AI, particularly ChatGPT, into education. Additionally, the term "medical education" emerged 12 times, highlighting the importance of the application of ChatGPT and AI in medical education. This reflects the recognition of AI's potential to enhance medical training, improve diagnostic accuracy, and support the educational journey of medical professionals [66], [67].

Researchers mentioned "higher education" 10 times, focusing on using ChatGPT and AI in tertiary education settings. Researchers are interested in exploring how AI can contribute to curriculum development, personalized learning experiences, and enhance higher education practices. These findings underscored ChatGPT and AI as relevant educational topics, providing invaluable insight into trends and areas of focus within academic communities and further elucidating their applications in educational settings [68], [69].

Moreover, the data revealed a moderate frequency of other noteworthy keywords, namely "generative AI," "large language models," and "natural language processing". These keywords signify an interest in developing AI models that generate human-like languages while effectively processing natural languages. The keyword' academic integrity' also appeared seven times, underscoring its significance within academic settings. Our analysis indicated that AI plays a pivotal role in detecting plagiarism, managing assessments, and promoting ethical educational practices. Its incorporation into data serves as an indicator for exploring the concept of academic integrity in AI. Lastly, "chatbot" was mentioned six times, indicating discussions surrounding the development and implementation of AI systems that simulate human communication and interaction. Chatbots have applications in education, customer service, and various business sectors, thus emphasizing the exploration of chatbot-related aspects within the context of AI.

In summary, the frequently identified keywords in the analyzed data provide valuable insights into the dominant themes and areas of interest. The active usage of these keywords highlights the significance of AI, particularly in education, language generation, natural language processing, medical education, higher education, academic integrity, and chatbot development within a given context. These findings contribute to the existing body of knowledge on AI and serve as a foundation for further research and exploration.

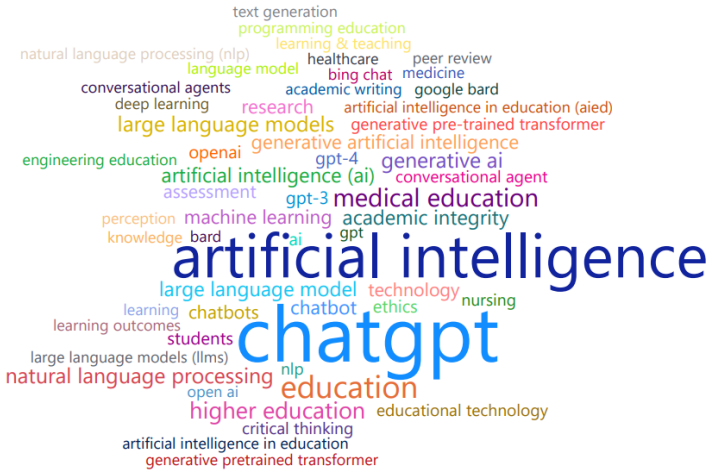

Figure 8. The most frequent words

3.9. Co-occurrence networks

Figure 9 illustrates a co-occurrence network representing the relationships between different terms within the context of our research. In this network, the terms are connected based on their co-occurrence frequency, signifying the degree to which they appear together in the dataset. Based on co-occurrence network analysis, we can infer the following regarding ChatGPT in education. We interpreted several findings in an academic setting. Firstly, we observed a significant correlation between "ChatGPT" and "chatbot." This indicates that the educational applications of ChatGPT revolve around chatbots. Chatbots enable more responsive and adaptive interactions between users, students or instructors, and AI systems in educational contexts. Second, we found an association between "ChatGPT" and academic integrity, suggesting that research and implementation of ChatGPT in education prioritize maintaining academic integrity as a core principle. We emphasize the importance of adhering to ethical standards and upholding academic integrity using the ChatGPT [70].

Furthermore, ChatGPT was widely implemented in higher education institutions, as evidenced by the strong connection between "ChatGPT" and "higher education." The integration of ChatGPT contributed to curriculum development, enhanced student engagement, and personalized learning experiences in higher education [69], [70]. Additionally, ChatGPT found application in "medical education," indicating its usage in the healthcare field [38], [63]. Medical professionals have benefitted from ChatGPT in terms of training, learning, and improved service quality [66], [67]. Figure 9 shows that ChatGPT in education encompasses

various domains, including chatbot usage, academic integrity consideration, and widespread implementation in higher education and healthcare settings [71], [72]. These findings provide valuable insights for researchers and educational practitioners to develop innovative and responsive educational practices.

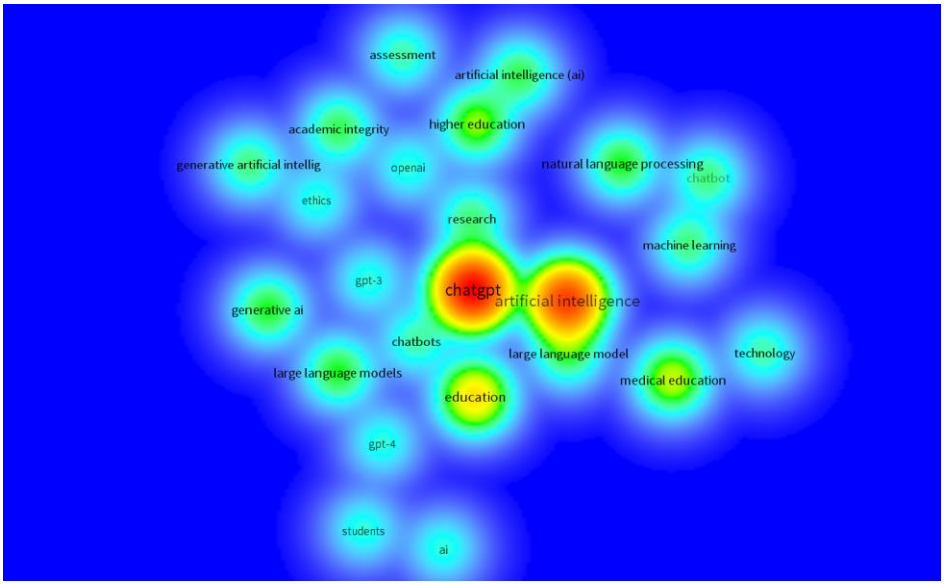

Figure 9. Co-occurrence network by keywords

4. CONCLUSION

The present study aims to understand the current research trends, challenges, and applications of ChatGPT in educational settings. The integration of AI within education presents a constellation of opportunities, ushering in the potential to elevate learning experiences, individualize instruction, and fundamentally reshape the role of educators. Nonetheless, this transformative transition engenders intricate challenges concerning assessment methodologies, digital literacy proficiency, and ethical considerations. As we cast our gaze forward, fostering collaborative and interdisciplinary dialogue within academic disciplines and with outside actors and stakeholders is imperative. This collective discourse among researchers, educators, and policy-makers serves as a compass that guides our journey toward harnessing AI's potential to catalyze a potentially positive revolution within the educational landscape.

We acknowledge certain limitations of this bibliometric analysis. One limitation is the exclusive use of the Scopus database as a data source. While Scopus is widely recognized and comprehensive, it is important to note that other databases, such as Web of Science (WoS) and IEEE Xplore, offer unique coverage and different perspectives on the scholarly literature. Relying solely on Scopus may result in missing relevant publications from other databases. Including additional databases such as WoS and IEEE Xplore could provide a more comprehensive and holistic view of the research landscape in the chosen field.

Exploring multiple databases would allow for a more thorough analysis, capture a broader range of articles, and expand the scope of the study. This approach can help mitigate the biases or limitations associated with using a single database, leading to a more robust analysis of the research output and trends within the field. Researchers should consider the strengths, limitations, and coverage areas of each database. Thus, future research could benefit from incorporating multiple databases to obtain a more comprehensive understanding of the scholarly landscape and to enhance the validity and generalizability of the findings.

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