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Research Article

Exploring the Growth, Distribution, and Impact of ChatGPT in Enhancing Higher Education Literature: A Bibliometric Analysis

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ABSTRACT

Background: ChatGPT, a generative AI model developed by OpenAI, has influenced higher education through research, teaching, and learning. This study investigated the global trends in scholarly publications on ChatGPT in higher education. Methods: Analysis of 481 Web of Science publications (1991–2023) using Bibliometrix (R) and VOSviewer tools examined key bibliometric indicators, including growth rate, citations, authorship, and subject domains. Results: Publications showed 9.81% annual growth, averaging 4.46 years of age and 12.02 citations per document. Journal articles comprised 88% of publications, with an average of 4.86 authors per paper and 20.58% international collaborations. The United States led with 190 publications (CPP, 18.83), followed by China (74, CPP, 10.50) and England (27, CPP, 9.26). The top fields included Computer Science (40.33%), Medical Informatics (19.34%), and Health Care Sciences (13.31%). The Journal of King Saud University-Computer and Information Sciences was the most influential. The analysis revealed ten thematic clusters. Conclusion: ChatGPT research in higher education has shown rapid growth with international collaboration. The findings indicate its pedagogical impact and the need for ethical adoption guidelines.

Keywords: Bibliometrics, GPT, ChatGPT, AI, Higher Education, AI Advancement, Student Support, Scholarly Impact, Ethics.

INTRODUCTION

The integration of artificial intelligence (AI) in education has significantly evolved over the past decade [1–3]. As institutions strive to enhance learning experiences, AI-powered tools such as ChatGPT have emerged as transformative forces in higher education [4–6]. By leveraging advanced natural language processing (NLP) and machine learning algorithms, ChatGPT facilitates personalized learning, automated tutoring, and research assistance, extending beyond traditional teaching methodologies [7–9]. However, this transformation raises critical concerns regarding the balance between AI automation and human cognition, prompting ethical, pedagogical, and practical debates. A central issue in integrating ChatGPT into education is its impact on students' critical thinking (CT) skills [10, 11]. Proponents argue that ChatGPT enhances traditional learning by providing immediate feedback, supporting academic writing, and aiding in problem-solving. Conversely, critics warn of potential drawbacks,

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Research Article

including overreliance on AI-generated content, diminished engagement in deep learning, and ethical dilemmas related to plagiarism and the dissemination of misinformation. These divergent perspectives underscore the need to examine ChatGPT's role in higher education and its alignment with best pedagogical practices. The development of AI has been shaped by pivotal technological milestones (Figure 1). Alan Turing's foundational work in the 1950s introduced the Turing Test as a benchmark for machine intelligence [12]. In the 1960s, John McCarthy advanced symbolic AI research by developing LISP, a programming language tailored for AI [13]. The 1990s marked a paradigm shift toward machine learning, transitioning AI from rule-based systems to data-driven models that are capable of adaptation [14]. In subsequent decades, AI has expanded into specialized domains, including natural language processing (NLP), computer vision, and robotics, enabling systems to interpret language, analyze visual data, and interact with environments [15]. The 2010s witnessed transformative advancements in deep learning and large-scale language models, exemplified by OpenAI's GPT series. Models such as GPT-2 and GPT-3 have demonstrated unprecedented capabilities in generating coherent and contextually relevant text, thereby revolutionizing NLP [16]. Today, GPT-3 and GPT-4 continue to push the boundaries, enabling applications such as ChatGPT, which facilitates human-like interactions across diverse fields [17]. However, these advancements raise ethical concerns, including bias, misinformation, and societal implications of AI-driven automation [18]. As AI evolves, addressing these challenges through responsible innovation is imperative. This bibliometric analysis explores the scholarly discourse on ChatGPT in higher education, mapping its evolution, key contributions and emerging challenges. By examining publication trends, influential research, and ethical considerations, this study aims to illuminate ChatGPT's transformative potential, while critically assessing its implications for pedagogy and academic integrity.

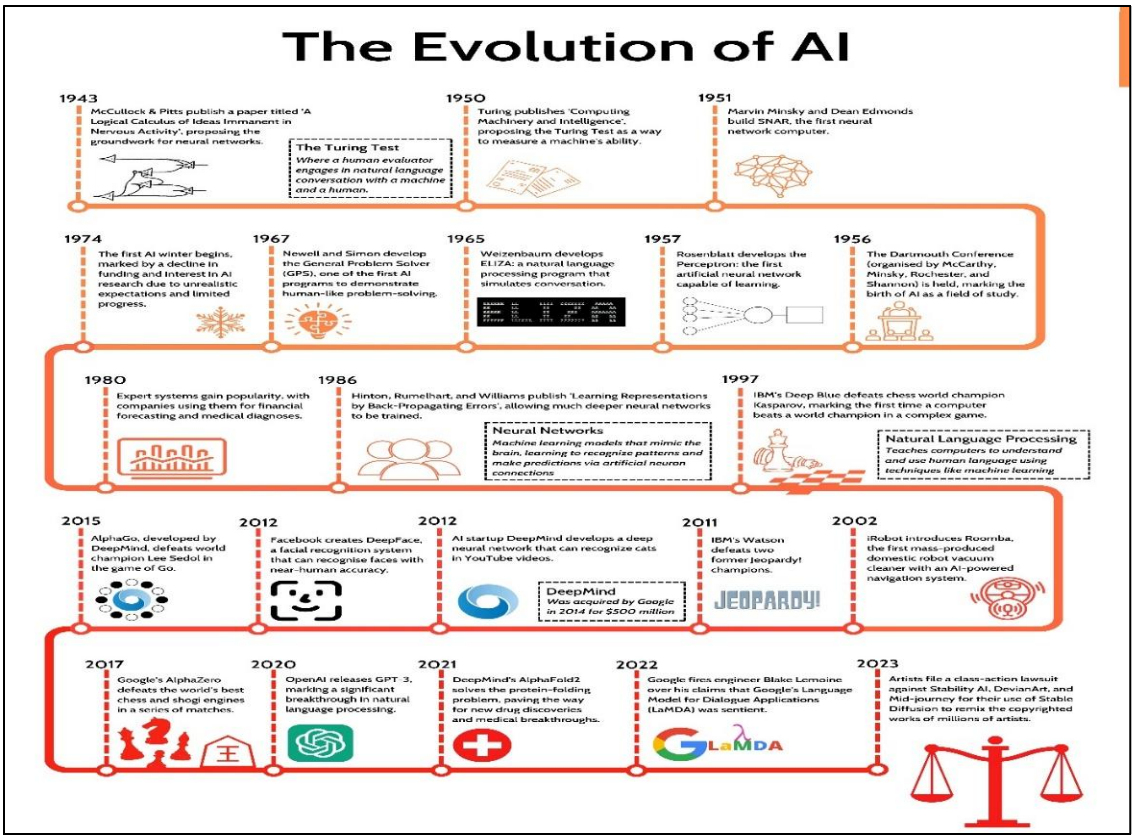

Figure 1: Journey from Artificial Intelligence to ChatGPT

LITERATURE REVIEW

The integration of ChatGPT and related AI technologies into higher education has attracted significant scholarly interest, with studies emphasizing both their transformative potential and the challenges they pose to educators. Researchers worldwide have underscored the diverse benefits of AI-powered tools for enhancing educational productivity, personalized learning, and research innovation. For instance, Sandu and Gide (2019) noted that in

Indian higher education, AI chatbots can streamline routine administrative tasks, reduce ambiguity, and improve communication and learning support [19]. Similarly, ChatGPT's capacity to analyze large datasets, model complex patterns, and enable predictive advancements is recognized as a powerful asset for academic research and lifelong learning Gulavani et al. (2022) and Xu et al. (2021) [20, 21]. Concurrently, AI-based assessment and feedback systems have shown promise in boosting student engagement and academic performance, as evidenced by Hooda et al. (2022) [22]. Scholars such as Dwivedi et al. (2023), Hirosawa et al. (2023), and Sallam (2023) have further acknowledged ChatGPT's utility in supporting scientific writing, literature reviews, healthcare research, and coding, while also highlighting its limitations, such as the lack of critical reasoning in AI-generated output [23–25]. However, ethical and pedagogical challenges have emerged alongside these benefits of AI. Mhlanga (2023) emphasized the importance of upholding core principles, such as privacy, fairness, transparency, and accountability, in AI adoption [26]. Particularly in online education, concerns have been raised about ChatGPT's potential to compromise academic integrity; Susnjak (2022) pointed out how its advanced text generation capabilities might facilitate cheating, necessitating new assessment strategies, such as oral examinations and robust invigilation systems [27]. Chatbots are increasingly integrated into user service systems in academic libraries; however, concerns persist regarding privacy and their ability to handle complex queries effectively (Kaushal & Yadav, 2022; Lund & Wang, 2023) [28, 29]. Although global research is extensive, contributions from South Asia, especially India, offer valuable localized insights but are limited in their bibliometric scope and scientometric evaluation. This highlights the gap in regional analyses of collaboration patterns, institutional productivity and citation impact. Bozkurt et al. (2023), Kasneci et al. (2023) and Tlili et al. (2023) stressed the need to foster digital literacy, critical thinking, and fact-checking skills among students and educators to ensure the ethical and responsible use of language models [30–32]. In line with this, academic institutions such as the Warwick Manufacturing Group are actively developing chatbot prototypes to explore innovative applications in pedagogy (Yang and Evans, 2019) [33]. Collectively, the existing literature reveals a growing consensus on ChatGPT's potential to enrich educational practices globally, while also calling for continued research to address ethical considerations, implementation challenges, and regional disparities in scholarly output.

The literature highlights the transformative potential of ChatGPT in higher education, particularly in academic writing support, research assistance, and personalized learning. While its content generation and synthesis capabilities offer substantial value, concerns remain regarding its ethical use, erosion of critical thinking, and academic integrity. Current research offers foundational insights; however, further empirical investigation is necessary to evaluate its long-term impact on scholarly standards and pedagogy. Achieving optimal integration requires balancing technological innovation, academic rigor, and ethical considerations.

Objectives

This study aimed to explore the following key aspects.

- ✓ The evolution of publications and their relative growth over time.
- ✓ Prominent authors, affiliations, and countries have contributed significantly to this field.
- ✓ Impactful publications and their scholarly influence.
- ✓ Changing research topics and emerging trends in the domain.

METHODOLOGY

A bibliometric analysis was conducted to explore ChatGPT's potential to enhance higher education. The Web of Science was accessed using the following search terms: (TS= ("ChatGPT" or "GPT-2" or "GPT-3" or "OpenAI" or "conversational AI" or "natural language processing" or "language models")) AND (TS= ("higher education" OR "education technology" or "University" or "College" or "Blended learning" or "Online learning")). A total of 481 search results were exported, and the VOSviewer [34] and Bibliometrix [35] packages were used for analysis and network visualizations. VOSviewer was used to visualize the co-occurrence of terms, co-authorship, co-citation, and bibliographic coupling networks. The R package Bibliometrix was used for quantitative bibliometrics, including citation and co-authorship analyses.

Results

Summary of the data

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Research Article

Figure 02 presents a bibliometric analysis of 481 publications from 261 sources between 1991 and 2023, highlighting the growing scholarly focus on ChatGPT in higher education. The field exhibits a steady annual growth rate of 9.81%, with an average document age of 4.46 years, reflecting both sustained and recent interest. It has achieved considerable academic impact, accumulating 5,782 citations (an average of 12.02 per document) and citing 17,633 references. Of these, 266 papers received funding, indicating increased institutional support for the field. The research is highly collaborative, involving 2,042 authors with an average of 4.86 co-authors per paper and only 38 single-authored papers. International collaboration accounted for 20.58% of the output, emphasizing the importance of global engagement. Most documents are journal articles (437), followed by conference papers (20), reviews (18), and a few editorials (five). Keyword analysis revealed 767 Keywords Plus and 1,571 author keywords, indicating conceptual diversity and a domain-specific focus.

Figure 02: Main information of the data

Figure 03 illustrates the growth and impact of the literature on ChatGPT in higher education from 1991 to 2023, showing a clear upward trend in publications and citations. The data revealed two distinct phases: in the first phase (1991–2017), publication activity was minimal, with only one or two papers per year and few citations. Notably, the only published article in 1991 received no citation. However, growth began in 2017, with 28 articles and 196 total citations. The second phase (2018–2023) shows a sharp acceleration in the growth rate. In 2019, there were 34 publications and 466 citations, followed by a significant increase in 2020, with 59 publications and 715 citations. The upward momentum continued in 2021, with 88 publications and 1,153 citations. The peak was in 2022, with 139 publications and 1,564 citations, the highest figures. This sustained rise in both output and impact underscores growing scholarly interest and highlights the field's strong potential for future development. The graph not only tracks this evolution but also upholds the expanding influence of ChatGPT-related research in higher education.

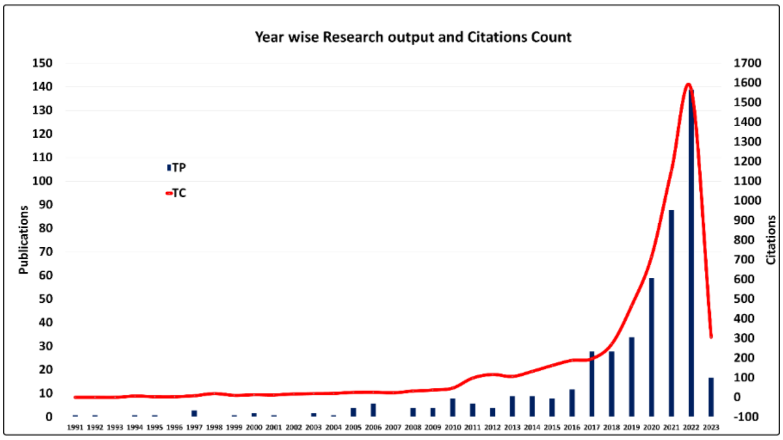

Figure 03: Year-wise Literature and Citations Growth

Preferred research areas

In recent years, the integration of artificial intelligence in education has grown significantly, with ChatGPT emerging as a crucial tool for academic tasks such as writing, summarizing, and addressing complex queries. A comprehensive review of its application across 70 academic disciplines highlights its potential to enhance higher education through

AI-based learning support. Table 01 outlines the top 15 research areas in which ChatGPT has been studied most extensively. Computer Science led the field, accounting for 40.33% of the total publications (194 papers) and the highest total citations (2,863), underscoring its foundational role in ChatGPT-related research. Medical Informatics (19.34%) and Health Care Sciences (13.31%) followed, with high citations per paper values of 16.26 and 18.05, respectively, indicating significant academic impact and relevance in healthcare applications. Although Educational Research ranked fourth in output (10.19%), its relatively low CPP (5.08) suggests either an emerging interest or a lower citation density. Notably, Library and Information Science exhibits a remarkable CPP of 26.00, despite contributing only 7.07% of papers, highlighting its concentrated scholarly impact. Similarly, Science and Technology Studies and Surgery reported high CPPs of 20.94 and 15.08, respectively, despite modest publication counts, suggesting that these areas produce highly cited, influential work. The sustained interest in General Medicine, evidenced by 2,780 usage counts since 2013, further underscores ChatGPT's growing clinical and policy relevance.

Table 1: Top 15 Most Preferred Research Areas

Research Areas	TP	TC	CPP	180-day Usage Counts	Since 2013 Usage Counts
Computer Science	194	2863	14.8	509	2997
Medical Informatics	93	1512	16.3	154	1100
Health Care Sciences	64	1155	185	104	849
Educational Research	49	249	5.08	417	1456
Engineering	47	318	6.77	212	805
Library & Information Science	34	884	26	106	879
General Medicine	18	107	5.94	241	2778
Science Technology	17	356	20.9	174	457
Telecommunications	17	55	3.24	82	258
Psychology	16	223	13.9	109	610
Linguistics	15	151	10.1	65	348
Surgery	12	181	15.1	9	57
Public Environmental Occupational Health	11	140	12.7	18	101
Mathematics	10	69	6.9	28	119
Neurosciences Neurology	9	24	2.67	33	67

TP=Total Publications; TC=Total Citations; CPP=Citations per paper.

Citation Distribution and Co-Citation Analyses

The citation distribution indicates a pronounced imbalance, with a minority of publications garnering most scholarly attention. Among the 481 papers examined, only 38 (7.9%) received 50 or more citations; however, these accounted for 1,375 citations, illustrating their significant influence within the field. Conversely, over half of the publications (243 papers, or 50.52%) received 10 or fewer citations, and 117 papers (24.32%) had not been cited at all, likely due to their recent publication or the limited reach of the journal. The most highly cited paper received 499 citations, underscoring the exceptional impact of a few selected studies. The data adhered to the Pareto principle, with approximately 20% of the papers (those with 25 or more citations) accounting for 60% of all citations (3,557 out of 5,927). This trend suggests that while interest in ChatGPT's role in higher education is increasing, the field currently depends on a relatively small core of influential publications. These foundational works are pivotal in shaping ongoing research and discourse, highlighting the importance of quality and relevance in achieving a scholarly impact.

Co-citation analysis, a fundamental bibliometric method, identifies research clusters in the artificial intelligence literature by examining the reference patterns. By applying a minimum citation threshold of 52, we selected 12 highly cited references from 481 papers for analysis. Using VOSviewer, we visualized the co-citation networks, revealing four distinct research clusters (Figure 04). The red cluster (Li, 2010; Rochefort, 2015, 2017; Weeks, 2020) represents the machine learning research. The green cluster (Mehrabi, 2015; Tvardik, 2018; Dynomant, 2019) focuses on natural

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Research Article

language processing, and the blue cluster (Sohn, 2017; Selby, 2018; Rabhi, 2019) encompasses computer vision studies. The yellow cluster (Bucher 2020; Shi 2021) specializes in robotics. This analysis demonstrates the multidisciplinary nature of AI research through its citation patterns.

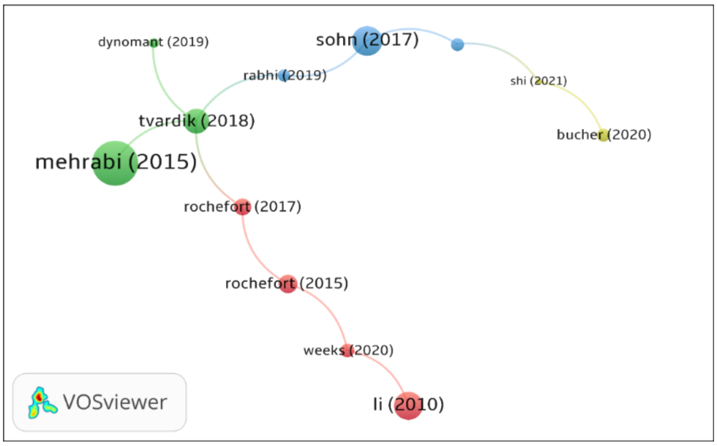

Figure 04: Top-cited papers Co-Citation Network

Most Productive and Impactful Journals

A total of 481 publications were distributed across 261 journals. Of these, 191 journals published only one paper, 41 published two, 13 published three, and 15 published between 11 and 18 papers each. Notably, one journal published exceptional 43 articles. This distribution highlights the wide-ranging scholarly interest in ChatGPT and its increasing role in enhancing academic discourse in higher-education settings. Evaluating the productivity and impact of these journals is crucial for identifying the most reliable and influential sources in this emerging field. The analysis of Table 2 reveals significant variations in productivity and impact among journals publishing research on ChatGPT in higher education. The Journal of King Saud University-Computer and Information Sciences leads in total publications (TP=43) but records a moderate (CPP=7.21), indicating high productivity with a modest impact. In contrast, the Journal of the American Medical Informatics Association stands out for its high scholarly influence, with a relatively lower number of publications (TP=18), but the highest CPP of 37.39 and a strong h-index (13) and g-index (18). Similarly, Computers in Human Behavior demonstrated a substantial impact with a CPP of 29.75 from only four publications. Journals such as the International Journal of Medical Informatics (CPP=18.44) and the Journal of Biomedical Informatics (CPP=17.25) also reflect high influence despite fewer publications than others. On the lower end, Mobile Information Systems showed minimal impact, with a CPP of only 0.25.

Table 2: Most Productive and Impactful Journals

S No	Journal Name	TP	TC	CPP	h_index	g_index
1	Journal of King Saud University-Computer and Information Sciences	43	310	7.21	8	16
2	Journal of the American Medical Informatics Association	18	673	37.39	13	18
3	BMC Medical Informatics and Decision Making	14	154	11.00	7	12
4	Journal of Biomedical Informatics	12	207	17.25	8	12
5	IEEE Access	11	43	3.91	4	6
6	Egyptian Informatics Journal	10	83	8.30	7	9
7	JMIR Medical Informatics	10	53	5.30	5	7
8	International Journal of Medical Informatics	9	166	18.44	5	9
9	Journal of Medical Internet Research	9	47	5.22	4	6
10	Methods of Information in Medicine	7	96	13.71	4	7

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2023, 8(4)
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https://www.jisem-journal.com/
Research Article

11	PLOS One	5	22	4.40	2	4
12	Educational Technology and Society	5	6	1.20	1	2
13	Computers In Human Behavior	4	119	29.75	4	4
14	Applied Sciences-Basel	4	38	9.50	1	4
15	Applied Clinical Informatics	4	19	4.75	3	4
16	Mobile Information Systems	4	1	0.25	1	1

TP=Total Publications; TC=Total Citations; CPP=Citations per Paper; TLS=Total Link Strengths

Figure 05 illustrates a co-citation map that delineates the interrelationships among the seven journals. This map was constructed using VOSviewer software based on the total number of citations each journal received, with a minimum threshold set at 40 citations. The size of each node and journal on the map corresponds to its citation weight, with larger nodes and journals indicating a higher citation frequency. The color of the nodes signifies the degree of relatedness among journals, with nodes of the same color forming a cluster. The length of the connecting lines between nodes represents the frequency of citation exchanges among journals, and the spatial distance between nodes on the map indicates the intensity of their relationship. Co-citation analysis identified three distinct journal clusters. Within the red cluster, three journals related to medical information were identified: the International Journal of Medical Informatics (TP=9, TC=166, TLS=7), JMIR Medical Informatics (TP=10, TC=53, TLS=2), and Methods of Information in Medicine (TP=7, TC=96, TLS=1). These journals exert a significant influence across various disciplines, including computer and information sciences, health informatics, decision-making, and biomedical informatics. Therefore, scholars seeking to deepen their understanding of ChatGPT's contributions to the higher education literature should consider these primary sources. The green cluster comprises two journals: the Journal of Biomedical Informatics (TP=12, TC=207, TLS=3) and BMC Medical Informatics and Decision Making (TP=14, TC=154, TLS=1), both of which primarily focus on biomedical research and healthcare. Additionally, the blue cluster includes the Journal of Medical Internet Research (TP=9, TC=47, TLS=1) and the Journal of the American Medical Informatics Association (TP=18, TC=673, TLS=3), both of which are pertinent to medical informatics and potentially influence the application of ChatGPT in health informatics. These findings underscore the key journals within their respective domains that have contributed to the discourse on ChatGPT's role in advancing higher education.

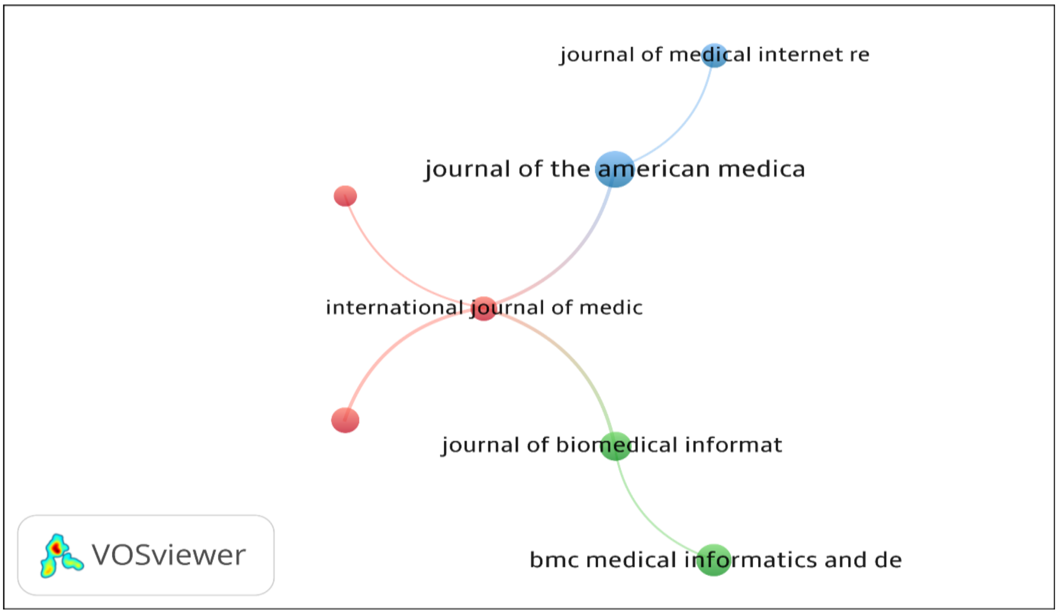

Figure 05: Co-citation Network Map of Journals

Table 5 lists the top 20 countries in terms of research performance. A total of 64 countries contributed to the production of 481 publications in this field. Among them, nine countries contributed two papers each, while another

Journal of Information Systems Engineering and Management
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Research Article

nine countries contributed one paper each. Notably, the United States accounted for 190 publications, while 16 other countries published between three and five papers. Additionally, four countries published between six and ten papers, and 12 published between 11 and 100 papers. The United States emerged as the most prolific contributor, with 190 papers, 3,577 citations, and a CPP value of 18.826. China follows closely, having published 74 papers, received 777 citations, and attained a CPP of 10.500. England ranked third with 27 papers, 250 citations, and a CPP of 9.259. England, Canada, Spain, and Germany contributed 27, 25, 23, and 22 papers, respectively. In terms of research impact, the United States (18.83), France (17.81), Germany (12.77), China (10.50), Spain (10.22), and India (10.16) exhibit high CPP values, indicating the substantial influence of their research outputs on the scientific community.

Table 5: Most Productive Countries

Rank	Country	TP	TC	CPP	TLS	Cluster
1	USA	190	3577	18.826	54	Red
2	China	74	777	10.500	22	Green
3	England	27	250	9.259	18	Blue
4	Canada	25	236	9.440	18	Lavender
5	Spain	23	235	10.217	8	Red
6	Germany	22	281	12.773	11	Red
7	Saudi Arabia	20	106	5.300	16	Green
8	Australia	19	141	7.421	17	Blue
9	India	19	193	10.158	4	Yellow
10	France	16	285	17.813	6	Red
11	South Korea	15	146	9.733	10	Green
12	Taiwan	13	48	3.692	3	Yellow
13	Morocco	11	30	2.727	0	Light Blue
14	Japan	9	50	5.556	6	Red
15	Egypt	8	60	7.500	2	Green
16	Turkey	7	40	5.714	1	Blue
17	Pakistan	6	48	8.000	12	Green
18	Italy	5	29	5.800	4	Red
19	Malaysia	5	6	1.200	2	Blue
20	Switzerland	5	25	5.000	2	Lavender

TP=Total Publications; TC=Total Citations; CPP=Citations per Paper; TLS=Total Link Strengths

Country co-authorship analysis is a crucial methodology for assessing international collaboration and influence within a specific academic discipline. The co-authorship network of the top 20 countries, as shown in Figure 06, offers valuable insights into the collaborative relationships among nations. The size of the nodes on the network map indicates the relative importance of each country, and the thickness of the connecting lines represents the strength of their collaborative ties. Furthermore, the proximity of nodes reflects the frequency of collaboration in the publication of scholarly works. A thicker line denotes a stronger collaborative relationship, whereas a shorter distance indicates a higher frequency of collaboration. The map's color scheme illustrates the diversity of the research directions. Through this analysis, six distinct clusters were identified: red, green, blue, yellow, lavender, and light-

Journal of Information Systems Engineering and Management
2023, 8(4)
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https://www.jisem-journal.com/
Research Article

blue. Among the top five countries with the highest total connection strength scores, the USA leads with a score of 54, followed by China with 22, and both England and Canada with 18. Australia occupies the fifth position with a score of 17 points. These countries actively engage in collaborative research and play pivotal roles in enhancing the quality of scholarly publications. Moreover, this study highlights the most robust link strength between countries. The USA and Canada exhibited the highest number of links, with a TLS of 11, followed by China, with a TLS of 8, and Germany, with a TLS of 6. With 48 links and 108 TLS, the network of 19 countries demonstrates a significant level of collaboration. This analysis provides valuable insights into international collaboration and the impact of publications from different countries. Consequently, the findings of this study can be utilized to identify potential areas for future collaborations and to design effective strategies for promoting research.

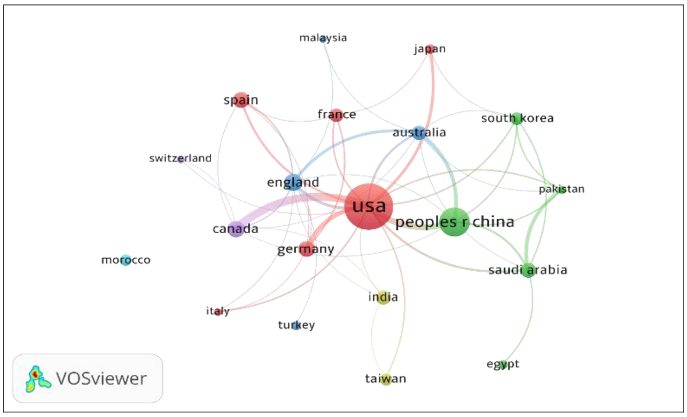

Figure 06: Top 20 Countries Collaborative Network Map

Table 6 provides a detailed analysis of the 25 most prolific authors, as assessed using various research metrics, including total publications, highly cited papers (HCPs), total citations, citations per paper (CPP), h-index, g-index, and total link strengths. This study analyzed the contributions of 2042 authors across 481 publications. Of these authors, 1857 (90.94%) contributed a single publication, 123 (6.02%) contributed two, 55 (2.7%) contributed between three and five, and seven contributed between six and eight publications. The collective output of the top 25 authors constituted 16.42% of all publications. Leading this group is Joshua C. Denny from Vanderbilt University, USA, with 7 papers and 2 HCPs. Denny's work demonstrates significant impact and productivity, with a total citation count of 483 and a CPP of 69. His h-index and g-index are 6 and 7, respectively. Second is Hongfang Liu from the Mayo Clinic, USA, who has published seven papers, including one HCP. Hua Xu from Vanderbilt University, USA, ranks third with 6 papers and 2 HCPs, achieving a total citation count of 307 and a CPP of 51.167. Xu's h-index and g-index are both 4. Yonghui Wu from the University of Florida, USA, holds the fourth position with 5 papers and a total citation count of 68, resulting in a CPP of 13.6. Wu's g-index is 8, indicating a substantial impact. Completing the top five is Jeffrey P. Ferraro from the University of Utah, USA, with four papers and a total citation count of 27, yielding a CPP of 6.750. Ferraro's h-index and g-index are both 3. The remaining authors also demonstrated varying levels of performance based on publication counts and citations. Noteworthy contributors include Dan M. Roden from Vanderbilt University, USA, with a high citation count of 366, and Qingxia Chen from Vanderbilt University, USA, who exhibited a substantial g-index of 6.

Table 6: Most Productive and Impactful Authors.

Rank	Author	Affiliation	TP	HCP	TC	CPP	h_index	g_index
1	Denny, Joshua C.	Vanderbilt University, USA.	7	2	483	69.000	6	7
2	Liu, Hongfang	Mayo Clinic, USA.	7	1	291	41.571	6	6
3	Xu, Hua	Vanderbilt University, USA.	6	2	307	51.167	4	4
4	Wu, Yonghui	University of Florida, USA.	5	0	68	13.600	3	8

Journal of Information Systems Engineering and Management
2023, 8(4)
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5	Ferraro, Jeffrey P.	University of Utah, USA.	4	0	27	6.750	3	4
6	Roden, Dan M.	Vanderbilt University, USA.	3	2	366	122.000	3	3
7	Aberdeen, John	Massachusetts Institute of Technology Research and Engineering (MITRE), USA.	3	0	98	32.667	3	3
8	Hirschman, Lynette	Massachusetts Institute of Technology Research and Engineering (MITRE), USA.	3	0	98	32.667	3	3
9	Folarin, Amos	University College London, UK.	3	0	87	29.000	2	3
10	Chapman, Wendy W.	University of California, USA.	3	0	40	13.333	2	3
11	Shen, Feichen	Mayo Clinic, USA.	3	0	34	11.333	3	3
12	Bian, Jiang	University of Florida, USA.	3	0	24	8.000	1	3
13	Yang, Xi	University of Florida, USA	3	0	24	8.000	3	5
14	Wang, Yanshan	Mayo Clinic, USA.	3	0	21	7.000	3	6
15	Malin, Bradley A.	Vanderbilt University, USA.	3	0	19	6.333	2	3
16	Chen, Qingxia	Vanderbilt University, USA.	2	1	134	67.000	3	4
17	Agrawal, Asha	King's College Hospital, UK.	2	0	85	42.500	1	1
18	Gorrell, Genevieve	University of Sheffield, UK.	2	0	85	42.500	2	2
19	Jackson, Richard	King's College London, UK.	2	0	85	42.500	2	2
20	Kartoglu, Ismail	InterDigital Europe, London, UK.	2	0	85	42.500	1	1
21	Roberts, Angus	University of Sheffield, UK.	2	0	85	42.500	2	2
22	Stewart, Robert	King's College London, UK.	2	0	85	42.500	2	2
23	Stringer, Clive	King's College Hospital, UK.	2	0	85	42.500	2	2
24	Wu, Honghan	King's College London, UK.	2	0	85	42.500	1	2
25	Dobson, Richard	King's College London, UK.	2	0	45	22.500	1	2
		Total	**79**	**8**	**2846**			

TP=Total Publications; HCP=Highly cited papers; TC=Total Citations; CPP=Citations per Paper; TLS=Total Link Strengths

Figure 06 presents a graphical depiction of the collaboration network among authors who have published at least two papers. The authors are categorized into five clusters based on the strength of their interconnections, with each cluster distinguished by a unique color. Data analysis identified 25 authors who met the inclusion criteria. Notably, authors in the red and yellow clusters have a more significant impact in terms of citations, despite having a relatively

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smaller number of publications than those in the green and blue clusters. This disparity is evident in the cumulative strength of the connections within each cluster, with the red cluster having the highest total number of links (16), while the green and blue clusters have the lowest total number of links (nine and seven, respectively). Among the authors, Ferraro is notable for having the fewest publications (4) and is associated with the lavender cluster. However, it is noteworthy that Ferraro possesses a substantial total link strength of 27, surpassing several authors in the green and blue clusters who have published more frequently than Ferraro. This observation suggests that Ferraro's work has had a remarkable impact in terms of citations, despite not having as extensive a publication record as some other authors in the network. The findings of this study indicate that authors within the red and yellow clusters are more likely to have a significant citation impact than their counterparts in the green and blue clusters. This discrepancy may be attributed to the quality of the research conducted by these authors, the influence their work exerts on the field, or the frequency with which other researchers reference their contributions to the field.

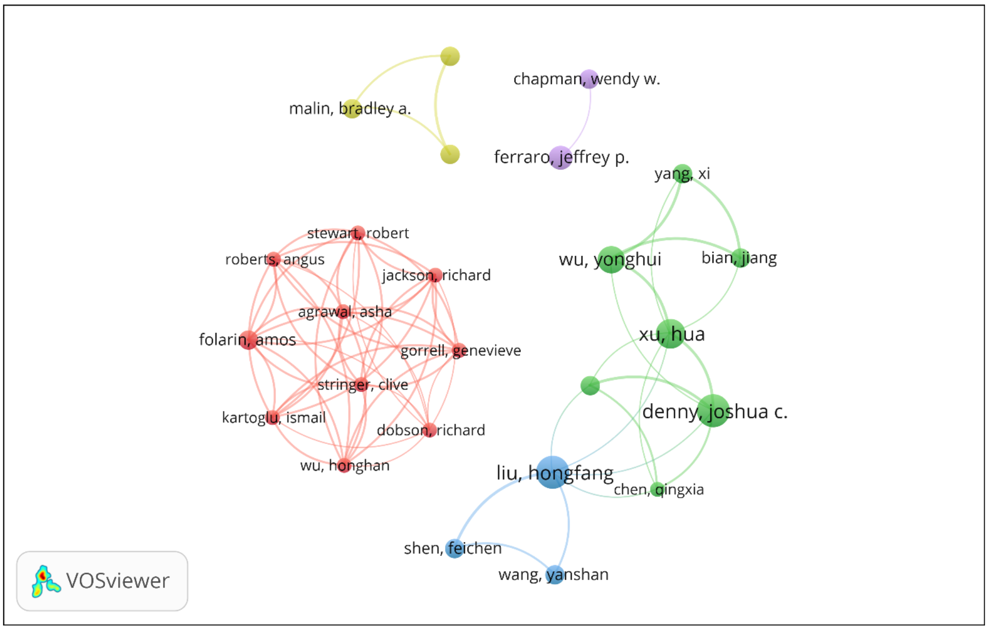

Figure 06: Top 25 Author Collaboration Network Map

A thorough examination of 481 publications identified 2,060 distinct keywords. Of these, 1,673 keywords appeared only once, indicating the diverse range of topics and concepts addressed in the research. Additionally, 321 keywords were mentioned between two and four times, suggesting recurring themes or subjects of interest within the publications. Furthermore, 42 keywords were mentioned five to ten times, reflecting a moderate level of emphasis or relevance to the study. Moreover, 30 keywords were mentioned 11–58 times, signifying a relatively higher level of importance within the analyzed publications. Notably, the term 'Natural Language Processing' was mentioned 206 times in the literature. VOSviewer was used to analyze the co-occurrence of the top 50 keywords with a frequency of three or more. The size of each node in the network corresponds to the frequency with which the respective keywords co-occurred with other keywords. The network comprises 10 distinct clusters, each representing a group of closely related keywords. The network included 264 links between keywords and a cumulative total link strength of 613 (Figure 07).

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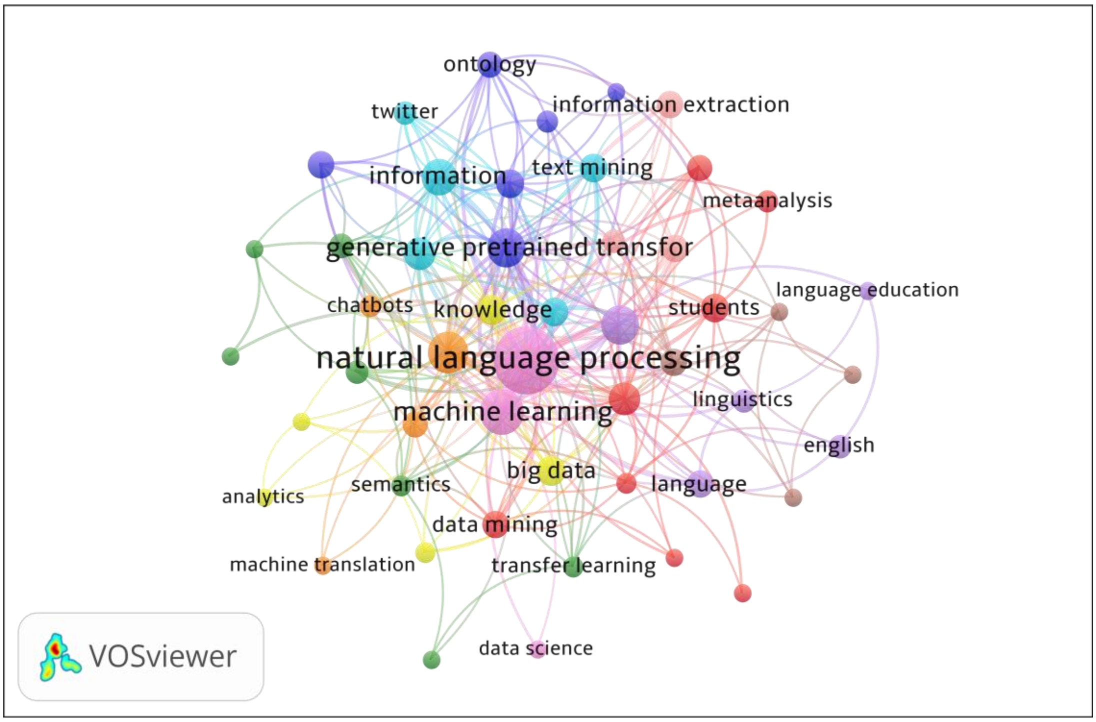

Figure 07: Top 36 All Significant Keywords Co-Occurrence Network

Table 7 lists the 50 most significant keywords identified through the co-occurrence network map. The inclusion of these keywords provides valuable insights into the potential implications of integrating advanced technologies into higher education. These technologies can transform higher education by personalizing learning pathways, facilitating communication and comprehension, and optimizing educational outcomes. Furthermore, they enable a deeper understanding of students' needs, thereby enhancing effective communication and comprehension in online learning environments. These findings are significant for researchers and educators seeking to enhance students' educational experiences in higher-education settings. Cluster 1 emphasizes the field of education and the practice of data mining, with the most frequently appearing terms being Data Mining, Education, Higher Education, Students, and Teachers. Cluster 2, meanwhile, focuses on information retrieval, semantics, and neural networks. Cluster 3 focuses on algorithms, generative pretrained transformers, and ontology. Cluster 4, on the other hand, is concerned with analytics, Big Data, and Knowledge. Cluster 5 focused on Artificial Intelligence, Language, and Linguistics. Cluster 6 emphasizes Classification, Information, social media, Text Mining, and Twitter. Cluster 7 focused on Chatbots, Deep Learning, Machine Translation, and Online Learning. Cluster 8, however, turns its focus to network analysis, Supervised Machine Learning, and Sustainability. Cluster 9, equally important, centers on Data Science, Machine Learning, and Natural Language Processing (NLP). Finally, Cluster 10 is concerned with Diagnosis, Information Extraction, and Named Entity Recognition.

Table 7: Top 50 Most Occurred Significant Keywords

Cluster	Keyword	Occ.	TLS	Cluster	Keyword	Occ.	TLS
1	Higher Education	20	38	5	Artificial Intelligence	34	63
	Students	12	30		Language	10	15
	Data Mining	11	17		English	6	8
	Education	9	14		Linguistics	6	9
	Meta-analysis	5	9		Language Education	3	5
	Teachers	4	12	6	Information	28	41
	Information Literacy	3	3		Classification	19	42
	Text Analysis	3	5		Social media	13	29

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2	Information Retrieval	8	14		Text Mining	13	27
	University	7	11		Twitter	6	13
	Semantics	4	9	7	Deep Learning	44	85
	Transfer Learning	4	9		Online Learning	9	16
	Automated Detection	3	5		Chatbots	5	9
	Data Warehouse	3	7		Machine Translation	3	3
	Neural Networks	3	3	8	Text Classification	11	19
3	Generative Pretrained Transformer	36	56		Network Analysis	3	4
	Algorithms	13	20		Supervised Machine Learning	3	6
	Word Embeddings	10	14		Sustainability	3	8
	Ontology	9	19	9	Natural Language Processing	206	263
	Semantic Similarity	5	8		Machine Learning	58	111
	E-Learning	3	7		Data Science	3	3
4	Knowledge	15	33	10	Information Extraction	11	17
	Big Data	14	31		Diagnosis	10	21
	Learning Analytics	4	7		Named Entity Recognition	7	16
	Analytics	3	5				
	Social Network Analysis	3	7				

Occ.=Occurrences; TLS=Total Link Strengths.

DISCUSSION AND FUTURE DIRECTION

The integration of AI-driven tools, such as ChatGPT, into education is transforming traditional pedagogical practices, presenting both transformative opportunities and significant challenges. This study highlights key trends in ChatGPT research, emphasizing its rapid adoption in higher education and critical debates surrounding its use. The following discussion synthesizes the scientific landscape of this field, focusing on recent progress, contributions by leading scholars and institutions, emerging research trends and unresolved challenges. Bibliometric analyses have shown a steady increase in ChatGPT-related research over the past decade, with a notable rise in citations and international collaboration [36, 37]. The United States, China, and the United Kingdom have emerged as leading contributors, with institutions such as Stanford University and MIT playing pivotal roles in advancing this discourse [38]. ChatGPT's applications in education have expanded beyond basic question-and-answer functionalities to include adaptive learning environments, automated grading systems, and academic writing support [39]. While a growing body of literature underscores ChatGPT's potential to revolutionize education, there is a pressing need for qualitative studies to evaluate its pedagogical efficacy and long-term implications [40]. Furthermore, multidisciplinary collaborations that integrate insights from education, psychology, linguistics, and computer science have enriched this field. However, empirical validation of the impact of ChatGPT on learning outcomes remains limited.

ChatGPT offers numerous benefits, such as real-time tutoring, personalized feedback, and improved accessibility for students with disabilities [41]. Its capacity to aid research, academic writing, and language refinement makes it a valuable asset for promoting inclusive and interactive learning environments in the future. Nonetheless, concerns remain regarding overreliance on AI-generated content, which might encourage passive learning and impede critical thinking [42]. Ethical challenges, including plagiarism, misinformation, and algorithmic bias, further complicate the reliability of the tool [18]. To address these issues, educators must establish guidelines for the ethical and responsible use of ChatGPT, ensuring that it complements rather than replaces traditional learning methods. A critical concern raised in the literature is whether ChatGPT enhances learning or merely automates responses, potentially undermining cognitive development [43]. Similar to a pilot relying on autopilot, students may acquire surface-level knowledge without developing critical thinking skills. To counter this, AI should be positioned as a learning enhancer, rather than a substitute for active engagement. Educators can design assessments that require students to critically evaluate and refine AI-generated content, fostering deeper intellectual engagement [39]. Integrating AI literacy into curricula can help students understand the limitations and biases of AI technologies, thus promoting a more critical and informed approach to their use. Future research should prioritize longitudinal studies to assess the long-term impact of ChatGPT on student learning outcomes [41]. Investigating the ethical implications of AI in education, particularly concerning academic integrity and bias, is essential for developing robust policies to address these issues. Additionally, research should explore the best practices for integrating ChatGPT into curricula in ways that complement, rather than displace, traditional pedagogy. Psychological and behavioral studies on student perceptions and interactions with AI tools can provide valuable insights into optimizing engagement and the learning outcomes. Finally, addressing disparities in AI accessibility across socioeconomic backgrounds is crucial for ensuring equitable and inclusive AI-driven education in the future.

CONCLUSION

The integration of AI-driven tools, such as ChatGPT, into education signifies a transformative shift in teaching and learning, presenting both significant opportunities and critical challenges. From its origins in the 1950s to the development of advanced models such as GPT-3 and GPT-4, AI has shown immense potential to enhance educational practices through real-time feedback, adaptive learning and academic support. However, concerns regarding overreliance, ethical implications, and the potential erosion of critical thinking skills necessitate a balanced approach to its implementation. While a growing body of research highlights ChatGPT's strengths in fostering inclusivity and interactivity, there remains an urgent need for qualitative and longitudinal studies to assess its pedagogical efficacy and its long-term impact. Addressing challenges such as academic integrity, algorithmic bias, and passive learning requires ethical frameworks, AI literacy, and instructional strategies that position AI as a supplementary tool, rather than a replacement for traditional methods. Future research should also explore disparities in accessibility and the psychological aspects of AI adoption to ensure equitable and inclusive AI-driven education. By thoughtfully integrating ChatGPT and addressing its limitations, educators can harness its potential to create engaging, inclusive, and effective learning environments while upholding the principles of critical thinking and academic integrity.

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