International Journal of Learning, Teaching and Educational Research
Vol. 23, No. 10, pp. 62-81, October 2024
https://doi.org/10.26803/ijlter.23.10.4
Received Aug 24, 2024; Revised Oct 11, 2024; Accepted Oct 23, 2024

Mapping the Frontier: A Bibliometric Analysis of AI in Tertiary Education

Hendra Sahputra Batubara, Nizwardi Jalinus, Fahmi Rizal and Ronal Watrianthos
Universitas Negeri Padang
Padang, Indonesia

Abstract. This article presents a bibliometric analysis of research on artificial intelligence (AI) applications in higher education over the past decade. Through computer-assisted analysis of 412 documents from the Web of Science core collection, we shed light on publication trends, productivity patterns, and conceptual development. Despite this exponential growth in research output, there remains significant uncertainty about the long-term impact of AI on pedagogical practices, learning outcomes, and the overall structure of higher education systems. The results show an annual production increase of 31.8% in research publications on AI in higher education, signaling scientific recognition of the disruptive potential. The concentration in renowned specialist journals on the topic of technology-supported learning is offset by the distribution of these journals across 206 multidisciplinary sources. With 10 publications, the Chinese University of Hong Kong is the leading contributing institution. China leads in the number of publications on AI in higher education, with 62 articles, followed by the United States with 45 and the United Kingdom with 29. These regional anchors are driving progress in the field. Although there is strong collaboration, the research output remains spread across 1,182 scientists without established leaders, reflecting the diverse and emerging nature of the field. Topic modeling and keyword analysis mean an increasing examination of the connections to education systems, training, labor markets, and learning analyses. This highlights the tensions surrounding data ethics, academic integrity, and the disruption of the workforce as algorithms permeate admissions, advising, and teaching. Our examination of the anatomy of this rapidly growing field provides indispensable perspectives for guiding innovation. As techniques advance from theory to reality, continued empirical research to explore risks and opportunities will be critical to upholding humanistic educational values.

Keywords: Bibliometrics; Artificial Intelligence; Higher Education; Educational Technology; WOS

1. Introduction

Artificial intelligence (AI) has become a transformative force in countless areas, including education (Chassignol et al., 2018a). The past decade has witnessed remarkable advancements in machine learning techniques, enabling computer systems to perform tasks that traditionally required human cognition and decision-making (Chandiok & Chaturvedi, 2015). This rapid evolution of AI from speculative theory to practical application has far-reaching implications for higher education, presenting both unprecedented opportunities and critical challenges that demand immediate attention and rigorous investigation.

Driven by the expansion of computing power and the availability of massive data sets, AI has evolved from speculative theory to practical application, improving products, processes, research, and decision-making worldwide (Aphirakmethawong et al., 2022). Given its fundamental role in advancing human capabilities and knowledge dissemination, there is growing interest in whether and how AI can improve learning, teaching, and educational administration (Hemachandran et al., 2022; Mady & Niese, 2022).

The urgency of understanding AI's role in tertiary education is underscored by several pressing factors. The acceleration of AI integration is evidenced by the 31.8% annual growth rate in publications at the intersection of AI and education over the past 10 years, bringing the total to more than 400 documents in leading journals by 2023, based on the Web of Science Core Collection (WOS-CC) (Singh et al., 2021a). This exponential increase in research activity signals the potentially disruptive impact on pedagogy, policy, and educational practice (Bjola, 2022).

Moreover, as AI systems become more sophisticated, ethical and pedagogical concerns about data privacy, algorithmic bias, and the changing role of educators are becoming increasingly urgent, requiring immediate attention to ensure equitable and effective implementation. Although techniques such as machine learning, neural networks, and natural language processing show clear applications in adaptive learning, assessment automation, prediction of at-risk students, and other areas, major uncertainties remain about the long-term consequences for human development and knowledge production (Shen & Su, 2020).

There is a significant debate about whether, when and how AI could redefine the role of teachers. Curricula are changing, exclusion is increasing, and the nature of education itself is changing (Chassignol et al., 2018b). Despite the growing recognition of AI's potential to revolutionize higher education, significant gaps remain in our understanding of its current state and future trajectory. While individual studies have examined specific AI applications in education, there is a lack of holistic, data-driven overviews of the field's development and current state. The multifaceted nature of AI in education spans computer science, pedagogy, psychology, and policy, necessitating an integrative approach that has yet to be fully realized. Furthermore, the rapid pace of AI development makes it challenging to identify and anticipate emerging trends that may reshape higher education in the near future

This article presents a comprehensive bibliometric analysis and builds on recent bibliometric reviews that have examined the academic literature on artificial

intelligence and education to shed light on the emerging topology, institutional origins, discursive dynamics, and conceptual development of research on AI applications in higher education. For example, Chen et al. (2023) examined the use of artificial intelligence robots to promote precision education using bibliometric analysis.

The results showed that AI robots and chatbots are widely used in various fields of study. Another study by Jing et al. (2023) highlights the importance of adaptive learning in the contemporary educational landscape (Jing et al., 2023). Using bibliometric analysis, their results convincingly show that adaptive learning is not a fad, but rather solidifies AI's position as an important pillar in the interdisciplinary field of computer science and educational technology.

This study addresses these urgent needs and knowledge gaps by focusing specifically on higher education, while extending data collection to 2023 to capture the latest literature (Aria & Cucurullo, 2017). Using a credible and reputable database (WOS-CC) with current data and customized analytical methods, this review builds on and extends previous reviews of the computing literature to provide an updated perspective on AI integration in higher education (Birkle et al., 2020). By mapping the frontier of AI in tertiary education, this study aims to provide indispensable insights for researchers, educators, and policymakers navigating the complex landscape of AI integration in higher education.

2. Method

Bibliometrics represents a rigorous quantitative method for comprehensively synthesizing and identifying patterns in a large corpus of academic publications and their associated metadata (Ninkov et al., 2022) (Bond & Buntins, 2018). By using computational techniques to extract and analyze thousands of data points related to citation patterns, authorship, journal distribution, and temporal trends, bibliometric reviews provide an empirical compass to map the contours of scholarship in a particular research area (Watrianthos et al., 2022). Bibliometric methods exploit the extensive metadata of millions of scientific papers indexed in databases such as Scopus (Burnham, 2006), Web of Science (Birkle et al., 2020), and others (Thelwall, 2018).

By computationally searching these vast repositories, bibliometrics can reveal insightful topological structures and temporal dynamics associated with how knowledge is distributed and concentrated among authors, institutions, and journals (Atkinson, 2012). In this way, bibliometrics represents a powerful empirical technique for comprehensively representing the ebb and flow of the scientific literature on a research topic and synthesizing this understanding through data-driven visualization and measurement (Ronal Watrianthos & Yuhefizar, 2023). When used carefully, bibliometric reviews can provide indispensable panoramic views that guide future research and discovery (Atkinson, 2012).

This research uses bibliometric analysis to systematically examine the impact of artificial intelligence (AI) applications in higher education. This takes advantage of extensive metadata and the global coverage of scientific publications indexed in the Web of Science Core Collection (WOS-CC) database (Singh et al., 2021b;

Zhu & Liu, 2020). To assemble a robust data set aligned with the research objectives, in July 2023 the WOS-CC was searched to retrieve documents meeting several key criteria: publication date within a current 10-year period (2014-2023); peer-reviewed educational journals as specified in the WOS Educational Research subject category; a thematic focus on AI, recognizable by artificial intelligence or AI in titles, abstracts, or keywords; and relevance to higher education through the inclusion of terms such as 'higher education' or 'tertiary education.'

By systematically searching the WOS-CC using this tailored query, the resulting dataset included 412 relevant documents published in the last decade that sit at the intersection of artificial intelligence and higher education. This extensive corpus provides an empirical basis to illuminate several bibliometric facets of the development of AI research and AI discourse in scientific communities in recent years.

To examine key dimensions that include publication volumes, authorship patterns, institutional collaboration, journal priorities, and conceptual connections, we conducted an analysis using R, which represents an ideal programming language for performing bibliometric analysis, text mining, data visualization, and statistical computing functions, given its extensive scope. We leveraged the R ecosystem of specialized packages such as Bibliometrix, Biblioshiny, Tidytext, and others to implement core routines for parsing metadata, calculating metrics, and generating insightful visualizations (Aria & Cucurullo, 2017).

3. Result

A comprehensive bibliometric analysis of the Web of Science Core Collection database shows rapid growth and increasing scholarly interest in the emerging field of artificial intelligence (AI) applications in education. Over the last decade, 412 documents on AI in education have been published in 206 sources, representing an explosive annual growth rate of 31.8%. With an average age of just 2.51 years, these documents represent current and current research on an extremely dynamic topic.

Although the scientific importance is still moderate at about 5 citations per document, more than 15,000 references have been cited in this literature, indicating participation in an extensive knowledge base. A clear upward trend can be seen when examining the annual growth trajectory of both publications and citations of research articles on artificial intelligence (AI) in education, as shown in Figure 1. The blue line represents the volume of scientific articles per year, which increases sharply every year, indicating a significant increase in research output on the topic. The red curve, which indicates the annual citation count of these articles, is now also increasing, albeit more slowly.

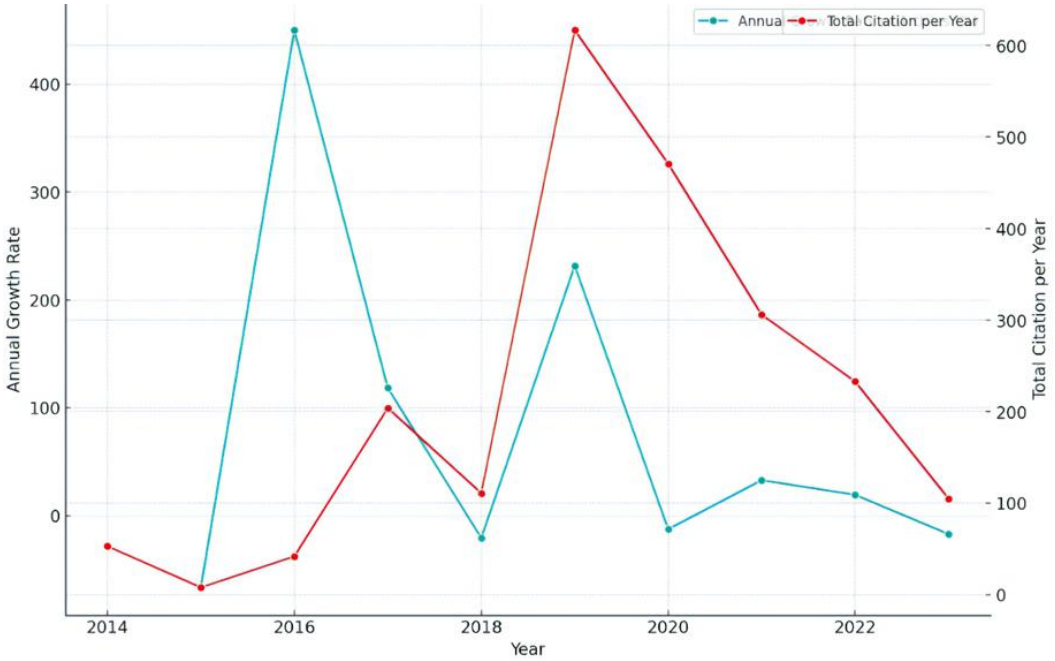

Figure 1: Annual growth rate of articles and total citations per year WOS-CC database (2014-2023)

This delay in citation accumulation arises from the natural passage of time required for published work to receive references. Nevertheless, the overall increase in annual citations represents a steady increase in the scientific importance of this corpus. This temporal visualization illustrates the double exponential expansion of AI education research, an explosion in studies published annually, followed by increasing waves of influence through increased citation rates.

Journal Analysis

A bibliometric analysis of the literature shows that research publications dealing with applications of artificial intelligence in education are concentrated in 206 sources in the study period 2014-2023, with journal articles being the predominant document type with 172 articles, followed by conference papers with 152. This indicates that this emerging field has penetrated both academic journals and venues for rapid dissemination.

The bibliometric analysis shows that the International Journal of Educational Technology in Higher Education is the predominant journal for advanced research on applications of artificial intelligence in higher education, as evidenced by its 24 publications, which represent up to 5.8% of the total documents in this field in the period examined (Table 1). Launched in 2016 by the Open University of Catalonia (UOC), this open access online scientific journal has accumulated 554 citations in the Web of Science Core Collection and has achieved notable influence in its short history.

Table 1: Most Relevant Sources

Journal	NP	TC	PY_Start	% Of 412
International Journal of Educational Technology in Higher Education	24	554	2016	5.8
Education and Information Technologies	15	112	2019	3.6
Education Sciences	12	8	2019	2.9
International Journal of Emerging Technologies in Learning	8	114	2020	1.9
Industry And Higher Education	7	22	2021	1.7

Examination of the source distribution for the literature on applications of artificial intelligence in science reveals a simultaneous concentration and diffusion of a quantitatively identifiable core of multidisciplinary journals focused on technology-enhanced learning. Figure 2 shows bibliometric zoning according to Bradford's law (Alvarado, 2016; Shenton & Hay-Gibson, 2011).

This bibliometric analysis describes the 14 most productive sources and publishes 34% of the articles as a concentrated core, reflecting interdisciplinary cross-fertilization. The distribution is reflected in the long list of 155 journals, which account for only 31% of the contributions and represent scattered scholarly interest. Although the average number of publications per source is 2.0, the median of 1 publication per source and a concentration index of 0.74 suggest the bias that results from numerous core publications is offset by predominantly single-paper publications. Simply put, the research encompasses a wide range of sources interested in the potential of artificial intelligence in higher education but remains focused on a group of leading multidisciplinary journals that are pushing the boundaries of knowledge.

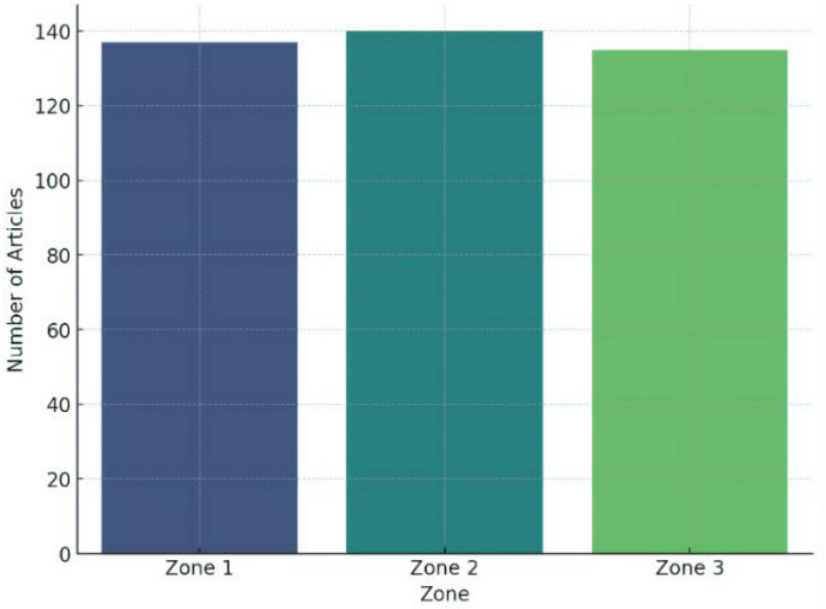

Figure 2: Number of articles by zone (Bradford's Law)

Author Analysis

Bibliometric analysis of authorship patterns reveals both strong collaborative activity and individual scholarship that characterize research on artificial intelligence applications in higher education. A total of 1,182 individual authors contributed to the 412 publications during the period examined. Of these, 83 authors (7%) published single-authored documents, accounting for 90 papers (22%) of the total. Therefore, the vast majority of results come from collaborative work, co-authorship being the rule. On average, each article lists 3.1 authors, reflecting the typical presence of multi-person research teams. The global spread of this emerging field is reflected in the fact that 17.23% of the publications were international co-authorships, that is, cross-border research collaborations.

As Table 2 shows, five authors are distinguished by their scientific achievements and the number of citations. Thomas K.F. is anchored at the Chinese University of Hong Kong. Chiu and Ching Sing Chai have authored five and four publications, respectively, and received twelve citations since 2020, underscoring the leading position of this institution. Meanwhile, David Baeres and Ana-Elena Guerrero-Roldn from Universitat Oberta de Catalunya have written four highly cited articles (30 citations), showing progress since 2021. Joseph E. Aoun of Northeastern University rounded out the top authors with three influential works cited (85).

Table 2: Most prolific authors

Authors	Affiliation	Articles	Total Citation	PY_Start
Thomas K. F. Chiu	Chinese University of Hong Kong	5	12	2020
David Bañeres	Universitat Oberta de Catalunya	4	30	2021
Ching Sing Chai	Chinese University of Hong Kong	4	12	2020
Ana-Elena Guerrero-Roldán	Universitat Oberta de Catalunya	4	30	2021
Joseph E. Aoun	Northeastern University	3	85	2017

However, when contextualized with the entirety of 412 publications by 1,182 unique authors in this research area, the five most cited authors listed in Table 2 together accounted for only 4.1% of the total output and 1.3% of the participating scholars. This distribution suggests a highly diverse and decentralized research landscape in the field of artificial intelligence applications in higher education. Although this small group of authors made disproportionately impactful contributions, their work represents only a fraction of the broader scientific community's efforts. This pattern indicates that the field is characterized by a wide range of contributors rather than being dominated by a few key figures. Such a distribution is often seen in emerging and rapidly evolving fields, where diverse perspectives and approaches contribute to the expansion of knowledge.

Figure 3 shows a line graph showing the share of authors in the number of documents written according to Lotka's law. In the graph, each point represents a category of authors based on the number of documents they authored, and the Y coordinate of the point represents the proportion of authors in that category. We

can see that the proportion of authors increases as the number of written documents decreases.

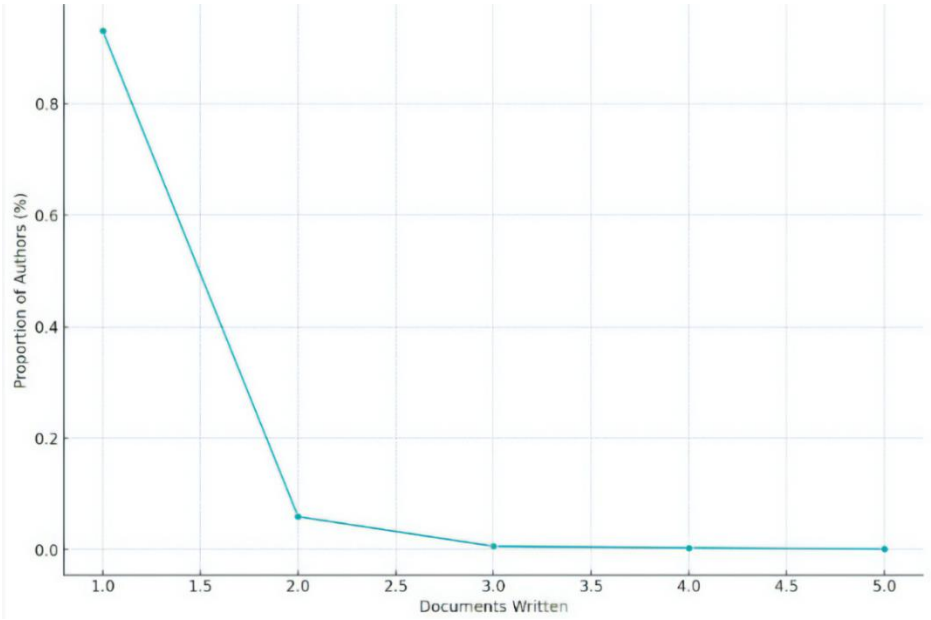

Figure 3: Proportion of authors by documents written (Lotka's Law)

This trend is consistent with Lotka's law, which states that a small number of authors will produce a large number of articles and that a large number of authors will produce a small number of articles (Saam & Reiter, 1999). An analysis based on Lotka's law shows that author productivity for AI education research closely follows the highly skewed distribution pattern seen in many scientific fields, with most results coming from a small proportion of lead authors (Pillai Sudhier, 2013).

Affiliations and Countries Analysis

With 10 publications, the Chinese University of Hong Kong is the leading institution advancing science at the intersection of artificial intelligence and higher education, closely followed by the Open University, which contributed 9 documents. Meanwhile, Hong Kong Polytechnic University and National Taiwan Normal University each published six articles, representing productive East Asian regional centers focused on technological integration in science. Finally, the Universidad Politcnica de Madrid rounds out the top five productive member organizations with six contributions, underlining Spain's commitment to this emerging field.

Table 3: Most prolific affiliations and corresponding author's countries

Affiliations	Articles	Countries	Articles
Chinese Univ Hong Kong	10	China	62
Open Univ	9	USA	45
Hong Kong Polytech Univ	6	United Kingdom	29
Natl Taiwan Normal Univ	6	Spain	25
Univ Politecn Madrid	6	Australia	14

The analysis of the corresponding author countries in Table 3 shows that China is the predominant source of publications with 62 articles, consistent with the high productivity of Chinese subsidiaries, such as Hong Kong and Taiwanese

institutions. Next, authors from the United States and the United Kingdom contributed 45 and 29 papers, respectively, providing additional anchors in this research area. Spain can now compete using the influential contributions of the Universidad Politcnica de Madrid.

However, in general, the United States contributed the most to the number of articles on AI in education. The United States contributed a total of 426 articles during this period. Figure 4 shows a stacked area chart showing the number of articles by country over time in the area of AI in education. In the graph, each colored area represents a country, and the size of the area corresponds to the number of articles from that country in each year. We can see that the total number of articles has increased over time and contributed to this growth to varying degrees. These five countries contribute a significant number of articles each year, although there are differences in the number of articles between them.

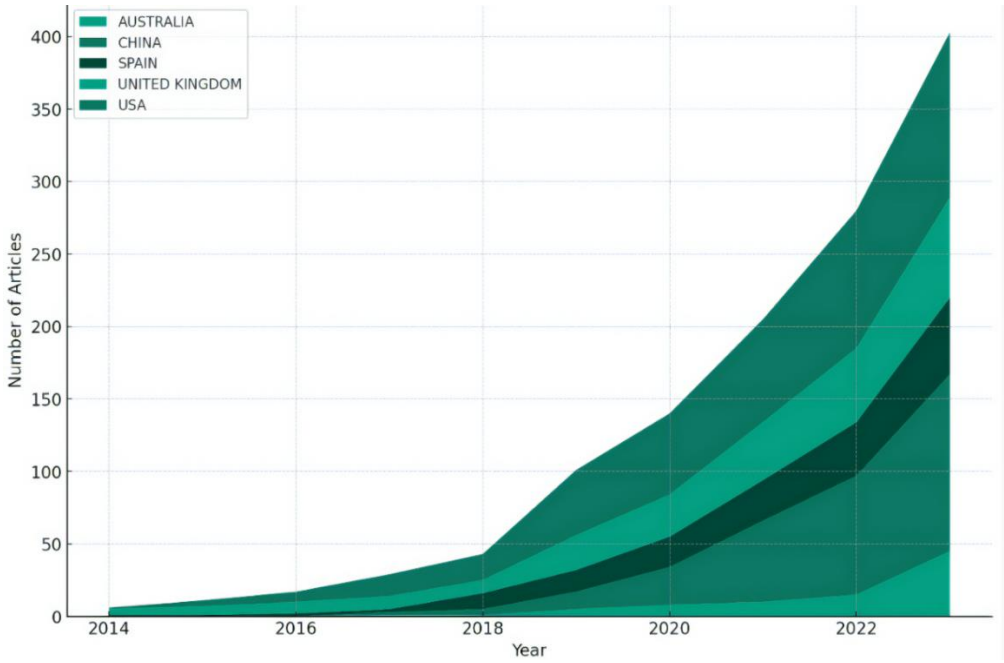

Figure 4: Number of articles by country (2014-2023)

Documents Analysis

The bibliometric analysis reveals a growing corpus of 412 documents examining applications of artificial intelligence technologies in educational contexts that have been indexed in the Web of Science Core Collection over the past decade, with a total of 2,149 citations. The average citation rate remains moderate, at 5.28 per document, reflecting the emergence and yet rapid development of this multidisciplinary research area at the interface between computer science and academic research.

The existing scientific format consists of 172 journal articles and 152 conference papers, indicating significant penetration of this emerging topic in both renowned journals, which provide a wide space of discourse and a rapid dissemination venue that enables real-time knowledge exchange. With annual growth rates exceeding 30%, this exponential expansion of the literature sheds light on the potentially transformative impact of artificial intelligence on pedagogical

practices, learning processes, and teaching systems in secondary and higher education institutions.

Table 4: Most Impact Documents

Title	TC	TC/Year
"Systematic review of research on artificial intelligence applications in higher education – where are the educators?"	292	58.40
"Predicting academic success in higher education: literature review and best practices"	90	22.50
"Robot-Proof: Higher Education in the Age of Artificial Intelligence"	84	12
"MOOC dropout prediction using machine learning techniques: Review and research challenges"	82	13.67
"Adoption of artificial intelligence in higher education: a quantitative analysis using structural equation modelling"	66	16.50

Table 4 shows the 10 most influential articles on artificial intelligence in education based on total citations, including highly cited works such as Zawacki-Richter et al. (2019) with 292 citations and Alyahyan and Dustegor (2020) with 90 citations. In particular, some of the most influential contributions have emerged in recent years (e.g. Alyahyan & Dustegor, 2020; Chatterjee & Bhattacharjee, 2020), which is consistent with the overall upward trend in total citations per year, as shown in Figure 1.

Keywords Analysis

The bibliometric analysis revealed that of the 412 documents dealing with applications of artificial intelligence technologies in educational contexts indexed in the Web of Science core collection over the past decade, a total of 1231 author keywords were found. Author keywords are assigned by authors themselves to highlight key themes and concepts in their publications. This directly reflects the author's research focus. The author's keywords are more numerous (1231 vs. 390 occurrences), more specific, and include newer terminology like ChatGPT and specialized methods like generative AI.

Table 5 shows that the keywords reveal the key themes and concepts in this emerging area. *Students* appear 28 times as Keyword Plus, reflecting the focus on the impact of AI on learners. *Higher education* now runs 22 times; so much of the research takes place specifically in the post-secondary context. More expected terms like *education*, *artificial intelligence*, and *technology* can also be found in the top keywords. Beyond these, keywords such as, *performance*, *design, system*, and *feedback* point to research on AI as a tool that improves educational performance, system design, and pedagogical feedback. Crucially, *Learning Analytics* appears eight times, highlighting the growing use of AI to analyze learning. Additionally, keywords such as *science, university* and *information technology* illustrate the multidisciplinarity of this cross-sectional topic.

Table 5: Most frequent words (Author's Keyword vs Keyword Plus)

Author's Keyword	Occurrences	Keyword Plus	Occurrences
artificial intelligence	130	students	28
higher education	102	higher-education	22
machine learning	29	education	21
education	18	performance	19
ai	15	artificial-intelligence	14
learning analytics	15	design	10

online learning	15	system	10
technology	13	technology	9
artificial intelligence (ai)	12	feedback	8
e-learning	12	learning analytics	8
deep learning	11	plagiarism	8
chatbot	9	science	8
chatgpt	9	university	8
digital transformation	9	achievement	7
appreciative inquiry	8	engagement	7
assessment	8	impact	7
gamification	8	information-technology	7
innovation	8	quality	7
academic integrity	7	acceptance	6
big data	7	adoption	6

4. Discussion

The exponential growth in research output observed over the last decade indicates the growing influence of artificial intelligence in the context of higher education and indicates that this young but rapidly growing field has the potential to have disruptive impacts on pedagogical practices, learning processes, and teaching systems. Although artificial intelligence has demonstrated that applications can improve personalized and adaptive learning (Qu & Ogunkunle, 2021), automated assessment (28), and increased teaching capacity (29) on scale, its long-term consequences remain unclear.

Our bibliometric analysis provides several novel insights that contribute significantly to the understanding of AI's role in higher education. Firstly, this study offers the first comprehensive mapping of the rapidly evolving landscape of AI in tertiary education over the past decade, providing a unique global perspective that reveals intricate patterns of international collaboration and knowledge dissemination. The identification of China as the predominant source of publications, followed closely by the United States and the United Kingdom, illuminates the global dynamics of AI research in education and points to potential hubs of innovation and expertise.

Secondly, our analysis reveals the highly interdisciplinary nature of the field. The distribution of research across 206 multidisciplinary sources underscores the cross-pollination of ideas from diverse fields such as computer science, psychology, and policy studies. This finding suggests a rich, multifaceted approach to integrating AI in tertiary education, which has not been previously articulated in the literature

The recent dominance of publications sheds light on the concerted scholarly effort to define the boundaries of what is happening. The concentrated activity of leading authors and institutions shows that centers are actively driving progress at the interface between artificial intelligence and science. In general, quantitative indicators highlight the impending transformation of artificial intelligence in higher education amid great uncertainty (30). While there is much speculation about the extent to which AI can replace or support teachers in the classroom, redefine skills requirements, and transform knowledge production, bibliometric

techniques reveal the increasing scholarly activity that is shaping our understanding and guiding the realization of these enormous potentials (31).

AI Resurgence in Education

The exponential increase in research output observed over the last decade is reflected by the annual growth rate of 31.8% and in more than 400 published documents on applications of artificial intelligence (AI) in the educational context. The timeliness of these publications, with an average age of just 2.51 years, demonstrates the timeliness of this investigation and implies that scientific work captures these new frontiers in real time. Although AI as an academic discipline has historical roots, its capabilities have reached new heights in recent years, facilitated by advances in machine learning, neural networks, and computing power (32). This technological advancement has fueled the increasing adoption of AI in countless areas of society, including education (33).

The surge in publications around AI and learning technologies belies intense scholarly attention to unlocking the promise of more personalized, adaptive, and intelligent instructional systems, while grappling with the cultural and ethical dilemmas posed (34). The evolutionary nature of artificial intelligence research, which builds on past discoveries to drive new horizons, aptly mirrors the exponential trajectory evident in this literature. In total, bibliometric indicators underscore the resurgent wave of academic activity seeking to comprehend AI's potentially transformative implications for pedagogy, policy, and educational practice at both the K-12 and higher education levels.

A unique aspect of our study is the temporal analysis of publication trends, which provides a novel perspective on the field's evolution. The exponential growth in research output, with a 31.8% annual increase, not only quantifies the field's rapid expansion but also signals a tipping point in the recognition of AI's transformative potential in higher education. This finding provides a data-driven basis for projecting future research trajectories and identifying potential paradigm shifts in educational technology and pedagogy

The limited period 2014-2023 for this bibliometric analysis was strategically chosen to capture the resurgent rise of artificial intelligence technologies in the educational context, as demonstrated by quantitative indicators over the last decade. It is clear from the contemporary literature that the observed steep growth trend began around 2012-2014, a turning point where several technical, financial and industry factors serendipitously came together to trigger a new wave of practical applications in pedagogy and learning.

The proliferation of digital learning systems led to massive datasets for data-driven predictive models, while, at the same time, the proliferation of affordable cloud computing solutions made it easier to implement more complex artificial intelligence architectures. Overall, this timely convergence of mature AI techniques, available data and capital, and receptive EdTech ecosystems has accelerated the rise in AI adoption at the primary, secondary, and tertiary levels documented in the academic literature.

As the first work in this research dataset, in 2014 Gyorgy Molnar examined the potential of advanced technologies such as AI, intelligent systems, machine

learning, and virtual assistants to transform higher education and learning environments (35). The article highlights the emerging relationship between AI as an enabling technology and its applications in higher education, although specific AI implementations are not discussed in detail. The article presents the future potential of artificial intelligence to reform pedagogical methods and learning systems.

While Molnar imagined the future potential of AI to reform pedagogy, Breines and Gallagher's article illustrates the actual development of basic chatbots and automated agents to fulfill specific teacher functions at the University of Edinburgh. Through a community-driven research process, the authors worked with university stakeholders to design bots for purposes such as student onboarding, group formation, fostering collaboration, and collecting student feedback (36).

Other researchers conducted an experimental study with 123 tenth graders using chatbots as AI-based technology. Chiu et al. (2022) examined the effects of teacher support and student expertise (i.e., self-regulated learning and digital literacy) on students' intrinsic motivation and ability to learn with the chatbot (37). The research results showed that teachers' support and students' expertise influenced students' intrinsic motivation and competence to learn with the chatbot. While teachers were more successful at satisfying the students' need for relatedness, they were less successful at satisfying their need for autonomy. This research provides insights into pedagogical and design considerations when implementing AI applications and teaching practices.

The literature of the last decade confirms that the rise of AI applications in education, including higher education, is significant and is accelerating. From an initial introduction; to the hypothetical potential of AI and non-AI bot implementations; to exploring AI chatbots for learning, these documents trace the trajectory of the increasing adoption of artificial intelligence technologies to improve teaching and learning. The coming years will further illustrate the evolving role of AI in transforming education systems.

Emerging Topics and Implications

There is no doubt that the application of artificial intelligence (AI) in education deserves serious study. The rapidly increasing volume of research on AI in education is evidence that scientists recognize the ever evolving and potentially transformative role of this technology in the future of teaching and learning (38). Over the past decade, research activity around AI applications in higher education has increased significantly, and publication production on the topic has experienced exponential growth since 2016.

Our study's innovative use of topic modeling and keyword analysis has unearthed emerging trends that were previously unrecognized. The identification of five distinct topic clusters – ranging from AI interactions with students and pedagogy to concerns about academic integrity – provides a nuanced understanding of the current research foci and potential future directions. This granular analysis of research themes offers a unique roadmap for scholars and policymakers to identify underexplored areas and pressing concerns in the field

The analysis of author keywords and their publication schedule provides important information about the rapidly evolving landscape of artificial intelligence (AI) research in higher education, as shown in Figure 5. As the most common term, artificial intelligence refers to the growing scientific attention to AI technology methods. The average publication year for this keyword in 2021 signals a notable recent momentum, reflecting increasing interest in the potential impact of AI on universities. Related topics, such as machine learning, are seeing a similar increase in research activity. This increase in studies that denotatively examine key AI techniques in higher education contexts shows that the integration of algorithmic systems goes beyond the speculative possibility into concrete implementation and influenced policy.

Our research reveals a critical tension in the field that has not been previously articulated: the simultaneous concentration and diffusion of research output. While we identified a core group of prolific authors and institutions driving the field forward, we also found a remarkably wide distribution of contributions across 1,182 unique authors. This pattern suggests a field that is both consolidating around centers of expertise and rapidly expanding to incorporate diverse perspectives and approaches, a dynamic that has significant implications for the future development of AI in higher education.

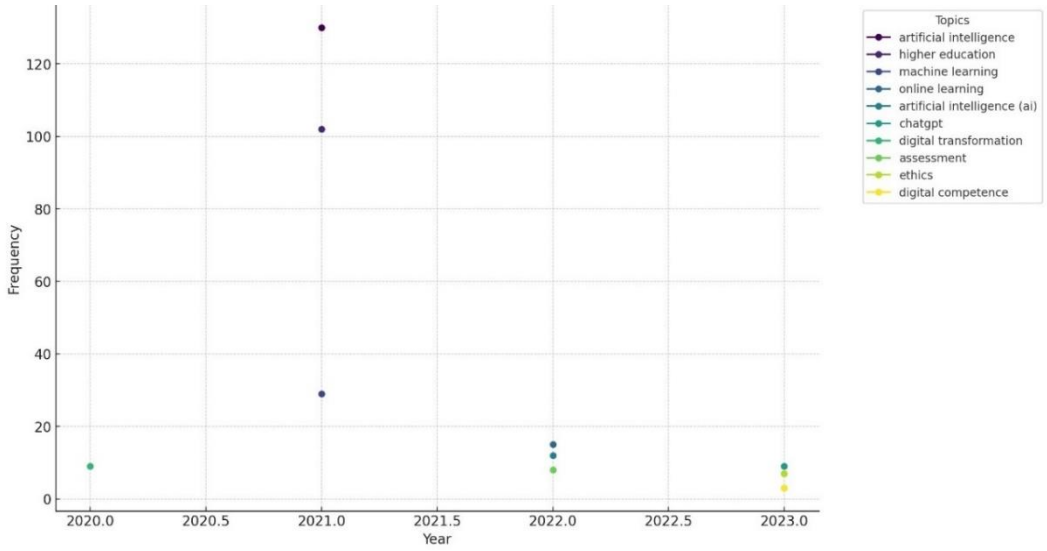

Figure 5: Emerging topic based on author's keyword

Furthermore, mainstream research dedicated to higher education as an application area embodies the industry's recognition that AI represents a source of impending transformation and not just a distant technological curiosity. Recent average publication years for keywords related to online learning, assessment, and ChatGPT show that scholars are moving beyond general predictions to address specific questions of pedagogical and ethical importance. The emergence shows that scholars urgently need to address how AI is transforming distance learning, assessments, academic integrity, and educational data. Meanwhile, keywords such as ethics, technology, and digital transformation reflect long-standing concerns and prove that the adaptation of AI is exacerbating existing challenges around values, inclusion, and the role of technology in learning.

The combined assessment of author keywords as well as keywords and terms algorithmically extracted from publication titles and abstracts provides a meaningful multidimensional perspective on the thematic development of research on artificial intelligence (AI) in higher education. The continued prominence of terms such as 'students' and 'higher education' underscores the focus on understanding the impact of AI on learners and institutions. The average release years of around 2022-23 suggest this is an issue of increasing urgency. Such benchmark terminology quantitatively anchors the analysis in the core application area of interest.

As shown in Figure 6, the increasing prevalence of keywords such as technology, innovation, and science underscores the examination of the scientific foundations that drive algorithmic advances and their potential to shape educational practice. Its rise recognizes AI as an emerging channel of educational transformation, not just a distant technical curiosity. Meanwhile, the increasing frequency and currency of terms such as online learning, assessment, and feedback indicate increased research activity at the intersection of AI and core educational activities.

Persistent keywords around academic integrity also show that the use of AI raises long-standing ethical dilemmas concerning honesty and inclusion. This practical orientation underlines the increasing debate about the compatibility of AI's potential with the central scientific and social missions of higher education. There are ongoing discussions about how to harness AI's capabilities while upholding academic values and ensuring equitable access to education.

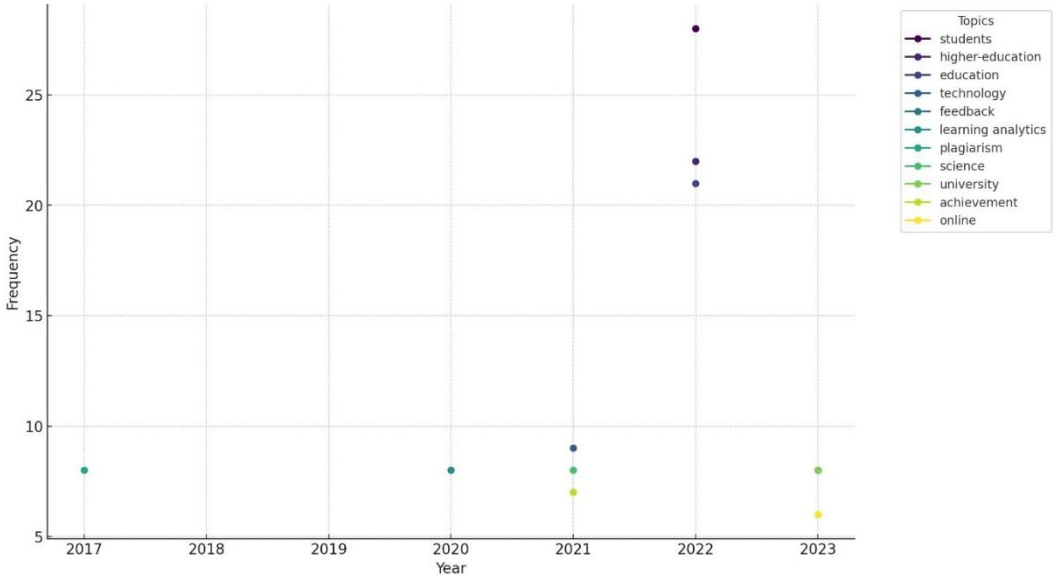

Figure 6: Emerging topic based on author's keyword

Table 6: Top 10 words associated with each topic focusing on tertiary education

Topic	Words
Topic 1	Students, Learning, Course, Group, Study, Chatbot, Model, Design, Results, Online
Topic 2	Digital, Education, Technologies, New, Higher, Skills, Training, Development, Technology, Industry
Topic 3	Academic, Integrity, Plagiarism, ChatGPT, Tools, Students, Writing, Research, HEIs, International
Topic 4	Learning, Data, Education, Learners, Analytics, Research, Educational, Higher, Online, Student
Topic 5	15 Teaching, Teachers, Education, Research, Intelligence, Artificial, Teacher, AI-based, Translation, Use

Table 6 provides insightful information on key current issues and concerns arising from the literature on artificial intelligence (AI) applications in higher education, based on preprocessed text analysis and non-negative matrix factorization (NMF) modeling (39). By retaining and focusing on keywords indicative of the university context during text preprocessing, NMF was able to identify five prominent topic groups and the ten most commonly used terms.

Several key themes stand out. For instance, Topic 1 focuses on AI interactions with students and pedagogy and includes words such as student, learning, learning, and chatbot. This suggests that researchers are paying increasing attention to the teaching and advisory functions of AI. Meanwhile, Topic 2 shows interest in AI's connections to education policy, training, and workforce transitions, with terms such as technology, skills, and industry. Topic 3 summarizes ongoing concerns about the potential impact of AI on academic honesty, with keywords such as integrity, plagiarism, and ChatGPT. Topic 4 highlights the data-driven nature of many AI techniques using terms such as learning, data, and analysis. Finally, Topic 5 is about exploring the impact of AI on educators themselves, including ideas about teaching, teachers, and translation.

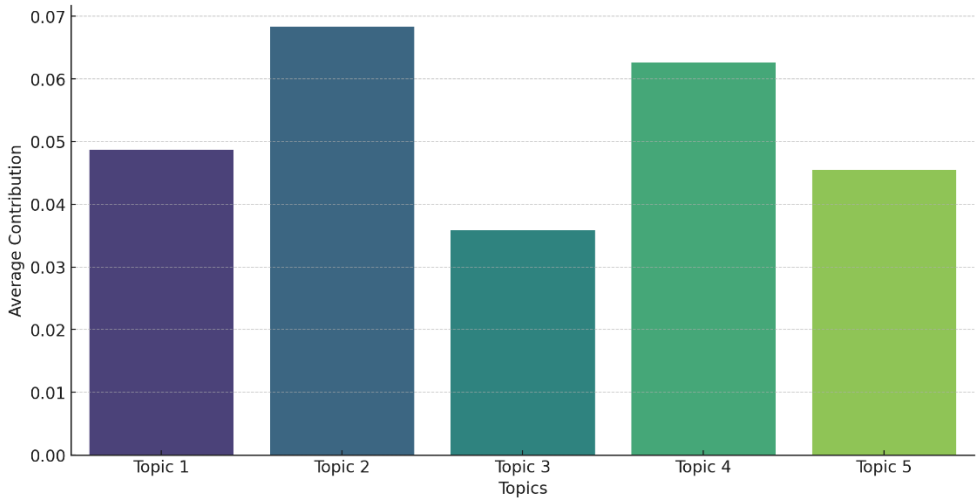

Figure 7: Average contribution of each topic using a Non-Negative Matrix Factorization Model

The result of topical modeling data provide a telling snapshot into two major fronts where the integration of artificial intelligence (AI) into higher education is generating significant research activity and policy debate. According to the bar graph (Figure 7), Topic 2 and Topic 4 appear to be the most relevant. Topic 2 seems to be related to digital technologies in higher education, while Topic 4 seems to be related to learning analytics in higher education. Topic 2, which highlights terms such as technology, skills, and industry, summarizes new research that examines the connections of AI to education systems, training, and labor markets. This underscores the intensification of research into how higher education policies and practices can help address potential workforce disruptions and skills gaps associated with algorithmic systems.

Meanwhile, Theme 4, denoted by keywords such as learning, data, and analytics, represents increasing attention to the use of AI techniques to improve the analysis of educational data to provide insights into learner behavior, learning trajectories, and interventions. With increasing amounts of student data, college leaders are eager to explore how predictive analytics and adaptive learning algorithms can improve support services, instructional quality, and academic success. This thematic analysis quantitatively illuminates two key themes: disruption to the world of work and learning analytics, where AI is reshaping higher education amid profound opportunities and risks. Responsible innovation requires interdisciplinary insights to defend humanistic educational values.

5. Conclusion

This bibliometric analysis demonstrates the rapid emergence and intensification of research activities investigating artificial intelligence (AI) applications in higher education over the last decade. The 31.8% annual increase in published output is a scholarly recognition of the potentially disruptive impact on pedagogy, policy, and practice. Although techniques such as machine learning and neural networks show the potential to improve personalized and adaptive learning, automated assessments, predictive analytics, and scaling, significant uncertainties remain regarding the long-term impact on the role of educators, curricula, inclusion, and higher education.

Thematic analysis of this study shows that academia is increasingly grappling with pragmatic tensions related to data ethics, academic integrity, and workplace disruption. Our quantification of publication patterns shows how research has spread across hundreds of multidisciplinary sources, although the concentration on prominent journals focused on technology-enhanced learning characterizes key venues guiding progress. The rise of authors from China and institutions such as the Chinese University of Hong Kong demonstrates regional anchors that guide progress at the intersection of algorithmic techniques and academic research. In general, bibliometric indicators illuminate how the integration of AI into higher education teaching and administration evolves from theoretical potential to complex practical implementation that requires evidence-based governance.

Future Directions

Future research should expand bibliometric techniques by extending data collection to other multidisciplinary indices such as Scopus, Dimensions, or Lens to provide a more comprehensive and comprehensive understanding of research

activity and research impact. As algorithms become more autonomous, continuous monitoring is critical to understanding the diffusion patterns of AI research and applications. Additionally, qualitative studies should examine the attitudes of students, teachers, and administration toward new uses. Longitudinal impact assessments of AI interventions and cross-cultural comparison studies can strengthen the thin evidence base.

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