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Artificial Intelligence in Higher Education: A Bibliometric Approach

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Abstract: The world eagerly anticipates advancements in AI technologies, with substantial ongoing research on the potential AI applications in the domain of education. The study aims to analyse publications about the possibilities of artificial intelligence (AI) within higher education, emphasising their bibliometric properties. The data was collected from the Scopus database, uncovering 775 publications on the subject of study from 2000 to 2022, using various keywords. Upon analysis, it was found that the frequency of publications in the study area has risen from 3 in 2000 to 314 in 2022. China and the United States emerged as the most influential countries regarding publications in this area. The findings revealed that "Education and Information Technologies" and the "International Journal of Emerging Technologies in Learning" were the most frequently published journals. "S. Slade" and "P. Prinsloo" received the most citations, making them highly effective researchers. The co-authorship network primarily comprised the United States, Saudi Arabia, the United Kingdom, and China. The emerging themes included machine learning, convolutional neural networks, curriculum, and higher education systems are co-occurred with AI. The continuous expansion of potential AI technologies in higher education calls for increased global collaboration based on shared democratic principles, reaping mutual advantages.

Keywords: *Artificial intelligence, bibliometric analysis, higher education, Scopus, VOSviewer.*

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Introduction

Artificial Intelligence (AI), attracting attention and altering reality with computers that outperform their limitations and mimic human intelligence (Saranya & Subhashini, 2023), continues to be pivotal in uncovering a broad spectrum of advancements in the contemporary global landscape (Luckin et al., 2016). AI technologies are rehashing our lifestyle, educational system, marketplace, and other facets (Balaha & Hassan, 2023). It is presently proclaimed as a tool for helping upgrade and nurture the concept of a social welfare state. (Górriz et al., 2020). An increasing shift towards intelligence-enabled products and services has been observed with the advancement of robotics and computing technology (Brunette et al., 2009; Kuo et al., 2023). AI has been substantially deployed across broad sectors, from robotics to aircraft flight control, because of its adaptability and durability (Kurfess, 2003). The question, "Can machines think?" (Turing, 2009, p. 23) rendered the foundations of AI.

AI technologies have advanced since their inception, leading to a broader and evolving definition. AI encompasses the study and development of intelligent devices and sophisticated computer programs (McCarthy, 1988; Sabanovic et al., 2012). While AI aims to emulate human intelligence, it is not limited to biological means of observation. AI can be further viewed as the system's capacity to precisely analyse and comprehend large amounts of data and use them to develop formulae for self-paced learning and judgment (Tsai et al., 2020). In accordance with the recent definition, "AI is an applied discipline that aims to enable systems to identify, interpret, make inferences, and learn from data to achieve predetermined organisational and societal goals" (Enholm et al., 2022, p. 1713).

With their remarkable ability to influence how people think, act, and interact, AI-powered technologies play a crucial part in our daily lives. AI has a growing impact on different industries, including medicine, agriculture, engineering, and others (Alhumaid et al., 2023; Shandhi & Dunn, 2022; Wakchaure et al., 2023). On the other hand, forecasts about utilising computers in education have been made since the 1980s. However, despite over 40 years of talk, computers are not yet widely used in many educational settings. (Yuan, 2023). Recently, the emergence of AI has revitalised the predictions for the prospective phase of higher education. Developers and educators are now actively working to

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integrate AI into schools and higher learning institutions to revolutionise education by providing adaptive learning systems that can facilitate individualised instruction. (Alqahtani et al., 2023a; Kabudi et al., 2021). Because AI can change beyond how teaching and learning are organised, along with how learners will be assessed with and through data, the field of education is one of the most prominent fields influenced by AI (Gardner et al., 2021). The possibilities of AI in education have directly impacted how technology has been employed for teaching and learning since the 1970s to benefit the learning process and to optimise learners' accomplishments (Southgate et al., 2019). Notably, the market value of AI technology in education attained $1 billion in 2020 and is estimated to sustain a compound annual growth rate above 40% from 2021 to 2027 (Global Market Insights, 2023).

It is evident that the rapid advancement of new technologies and the computational abilities of new smart machinery are fundamentally tied to the growth of higher education (hereafter HE) (Al Ka'bi, 2023). The expanding application of AI significantly influences HE (Bearman et al., 2023). Moreover, the *NMC Horizon Report: 2017 Higher Education Edition* recognised adaptive learning systems as a major educational, technological breakthrough with a notable influence on higher educational institutions (Adams Becker et al., 2017). By using learner data to customise educational materials, tests, and timely feedback, AI can significantly contribute to facilitating adaptive educational environments (Bhutoria, 2022). AI-driven algorithms can automate many administrative activities, including enrollment, course calendaring, admissions procedures, and supporting educational decision-making with evidence, which reduces paperwork and the possibility of human mistakes (Chiu et al., 2023). With the capacity to offer customised and adaptable possibilities for learning, AI-driven Intelligent Tutoring Systems (ITS) are becoming a game-changing technology for education. This further provides tailored feedback to address individual learning needs, evaluate learning preferences, reinforce learning objectives, boost learner engagement, enhance time management, reduce costs, improve ICT skills, and offer unbiased guidance for improvement. (Akyuz, 2020; Latham et al., 2012). Additionally, AI enables possibilities for research in HE, allowing researchers to evaluate enormous datasets and find unseen associations and trends that ordinary investigators would miss (Salah et al., 2023; Weigel et al., 2022). AI also maximise easier searching across sources, exploring diverse topics, applying methods between fields, and combining research approaches for intricate subjects, fostering interdisciplinary, multidisciplinary, and transdisciplinary research (Pisica et al., 2023). AI technologies can also analyse learning patterns and deliver specific guidance for scholastic achievement (Siemens & Baker, 2012). Additionally, AI-enabled educational systems can be utilised to evaluate the classroom environment and involvement among learners, which helps detect vulnerable children in real-time and facilitates immediate intervention (Luckin, 2017). Hence, the utilisation of AI in HE shows substantial opportunities for the future.

The volume of scientific research exploring the prospective utilisation of AI in HE is growing, making knowledge analysis and summarisation critical. To the best of the investigators' understanding, there are only a handful of bibliometric studies despite the number of publications examining scientific investigations on the possibilities of AI in HE. For instance, an in-depth bibliometric analysis by J. Li (2023) of the broader landscape of big data and AI applications was centred on the common theme of education. Another study by Song and Wang (2020) examined AI educational research. However, it did not expressly undertake the bibliometric exploration of the scholarly output within the realm of HE. For this reason, the present study aims to carry out a comprehensive bibliometric examination over the publications on the prospective AI applications in HE that were published from 2000 to 2022 in the Scopus database. Here, we intend to find answers to the following research questions:

1. What is the distribution pattern of relevant publications on AI in HE across different years and countries?
2. How do the citation standings of relevant journals align with their Q-Value and h-Index?
3. What pattern emerges from examining authorship collaboration across different nations, institutions, and authors?
4. How are the relevant keywords distributed, and what pattern emerges in their trend over time?
5. What kind of pattern emerges from examining the co-citation analysis considering cited authors and references?

Literature Review

The increasing global augmentation of AI integration within HE (Hu, 2023) has prompted a thorough investigation of its ramifications in this field. This has made the researchers begin to explore the multiple domains of AI utilisation in HE through different focused studies and systematic reviews, thus providing valuable insight. For instance, the systematic review of Rangel-de Lázaro and Duart (2023) on incorporating AI and Extended Reality (XR) technologies notes the increased adoption of XR and AI resources in online HE in a post-COVID setting. Moreover, computer science and engineering disciplines appeared to integrate more with XR and AI technologies. Additionally, the systematic review by Zawacki-Richter et al. (2019) highlighted computer science and STEM as the primary disciplines of AI research in education. Meanwhile, Odden et al. (2023) demonstrated the potential of the AI-based Learning Assistant Model to catalyse institutional and cultural transformation in European higher educational settings. However, the regional focus of the study limits the generalizability of implementing such models in diverse educational settings. Further, Alqahtani et al.'s (2023b) review of the implications of AI integration into entrepreneurial instruction at Qatari higher educational

institutes signified the diverse potential of AI applications, emphasising the prominent influence of machine vision in teaching entrepreneurial skills. This insightful information signifies the need to customise AI applications to specific educational contexts to optimise learning outcomes.

Further, studies focusing on AI's multiple applications in academic domains, such as validating academic credits (Campos et al., 2016), facilitating online proctored examinations (Rahman, 2022), enhancing language teaching (Sharadgah & Sa'di, 2022), and its effects on learners' achievement (García-Martínez et al., 2023), highlights the versatile utility of AI for enhancing educational experiences. Moreover, emerging areas, such as AI-based mental health assessment (C. Wang, 2023), AI dialogue systems in English as a Foreign Language (Zhai & Wibowo, 2023), AI applications in medical education (Winkler-Schwartz et al., 2019), AI-based learning style assessment (Bajaj & Sharma, 2018), signify the expanding frontiers where AI's impact is being explored.

While focused studies and systematic reviews offer essential insights into the specific domain of AI's integration within Higher Education, a comprehensive bibliometric analysis (Ellegaard & Wallin, 2015) could provide a solid framework for synthesising these distinct contributions. Such an analysis would allow for an extensive view of the scholarly landscape, uncovering upcoming trends, thematic focus, and the evolving trajectory (Ellegaard, 2018) of AI applications in higher educational settings. For example, Hinojo-Lucena et al. (2019) conducted a meticulous bibliometric analysis from 2007 to 2017 using WoS and Scopus databases. Their findings revealed a significant increase in proceedings papers as the dominant publication format, with the United States being the top publisher.

In addition, Shukla et al. (2019) conducted a thorough bibliometric analysis extending 30 years, exploring the application of AI in engineering. Meanwhile, Hwang and Tu (2021) focused on using AI in mathematics education, revealing the prominence of intelligent tutoring systems in the field. Broadening the scope, Maphosa and Maphosa (2021) conducted an extensive bibliometric analysis of 283 articles across 59 countries, spotlighting the prominence of engineering and computer science sectors in AI research within Higher Education. The findings highlighted the leadership roles of China and the USA while showcasing a striking 78% surge in AI research in higher education over the past five years. Additionally, the comprehensive bibliometric analysis of Hajkowicz et al. (2023), from 1960 to 2021, reported a notable rise in AI adoption rates across multiple disciplines. This finding indicated the growing trend of AI applications beyond specific domains, pointing at promising multidisciplinary applications, potentially shaping the later phase of AI integration within HE.

However, despite these significant efforts and promising multidisciplinary advancements, the bibliometric study by F. J. Hinojo-Lucena et al. (2019) between 2007 and 2017 identified a critical gap. Regardless of widespread interest, the comprehensive integration of AI within HE still needs to be improved. This reveals limited comprehensive bibliometric studies addressing AI's holistic integration in HE besides raising interest in specific disciplines or levels. Further, this hinders a comprehensive understanding of developments and trends in the field, highlighting areas requiring further investigation. Moreover, it limits informed decisions on incorporating AI in HE and affects progress in understanding AI's impact on academic outcomes, student engagement, institutional effectiveness, and instructional process.

Methodology

This research analysed AI in HE through the utilisation of bibliometric analysis methodology. Bibliometrics is a valuable scientific tool extensively employed in diverse disciplines (Zhu et al., 2023). This analysis approach depicts evolving article and journal productivity trends, interconnections between publication and authors, and collaboration patterns through visual maps (Donthu et al., 2021; Zupic & Čater, 2015).

Data Source and Search Strategy

The article searching and data collection, conducted in July 2023, utilised Scopus, a widely established and comprehensive database for bibliometric analysis (Mongeon & Paul-Hus, 2016). This process involved three sequential phases: Defining the topic, scope, and eligibility criteria; Screening the articles; and including them, as depicted in Figure 1. The preliminary search string targeted articles on AI and HE, employing the relevant keywords outlined in Figure 1. Rigorous inclusion and exclusion criteria were enforced, specifying the document type as "Article" published in "English" within academic "Journals" between 2000 and 2022. The initial search strategy resulted in 3206 articles.

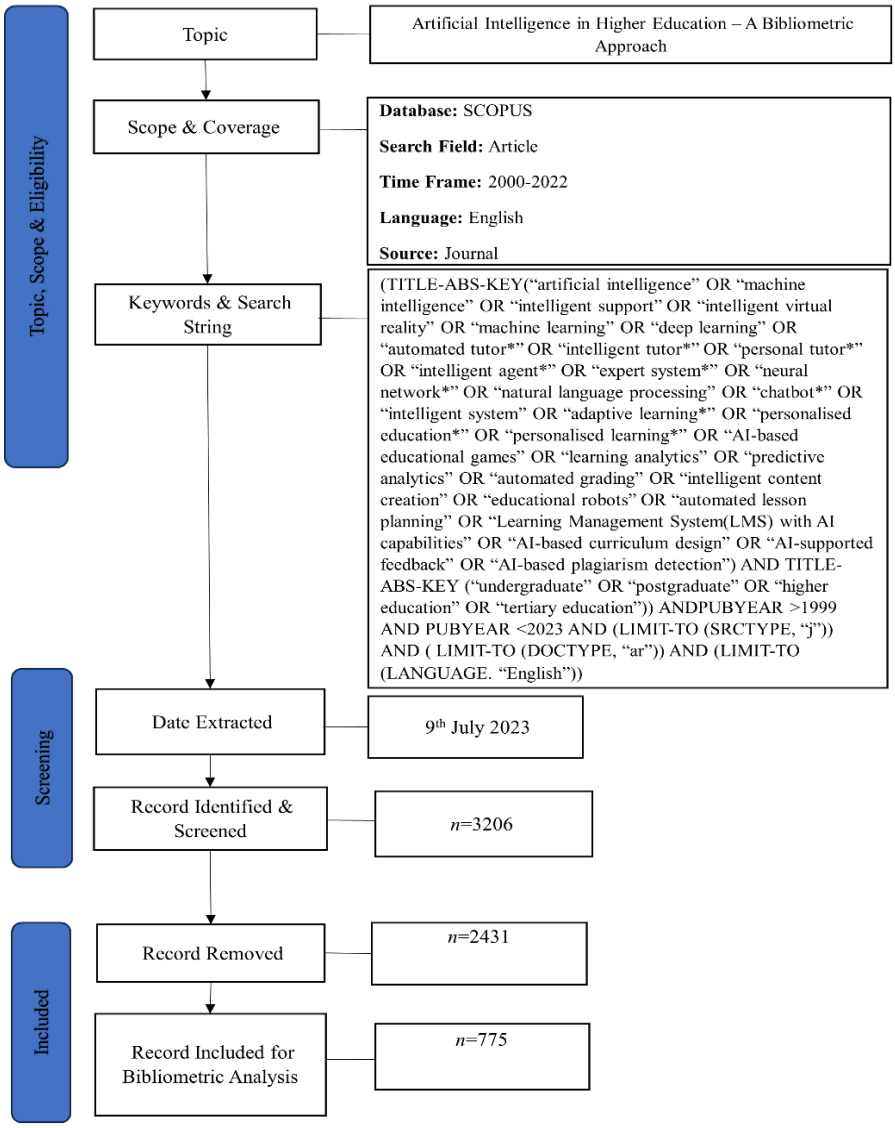

Figure 1. The Search Strategy Flow Diagram: Adapted From Zakaria et al. (2021)

Study Selection and Data Management

The articles identified from the initial search strategy included many subcategories of specific AI terms and computer science programs primarily focused on studying AI rather than the applications of AI technologies in HE. In this regard, following the initial screening phase of the search results, the researcher manually examined the publications to determine eligibility for inclusion in the included phase. The researcher reviewed the abstracts and titles of 3206 publications, assessing those that specifically cover the possibilities of AI in the realm of HE. At the end of this phase, 775 publications were identified and deemed suitable for further analysis using bibliometric techniques. The final data of the 775 articles from Scopus was then extracted in CSV Excel format. This dataset included keywords, citations, abstracts, and bibliographic and funding details. Subsequently, this information was transferred to VOSviewer 1.6.19, a free software application with a user-friendly graphical interface for text analysis and network visualisation (van Eck & Waltman, 2010).

Data Analysis

Initially, analysis was conducted on the distribution of publications across years and countries, examining journal metrics and publication citation counts. This exploration involved the entirety of the collected data from Scopus, which was exported into Excel and VOSviewer for deep insights. Subsequently, the network visualisations on co-authorship (authors, countries, institutions), co-occurrence keywords, and co-citation (authors, references) networks were developed using VOSviewer.

Results

The subsequent results have been obtained based on the research objectives. The findings of the study are displayed in Tables and Figures.

Distribution of Publications over the Years

The study examined the distribution of studies published between 2000 and 2022 in the Scopus database. The outcomes of this study are presented in Figure 2.

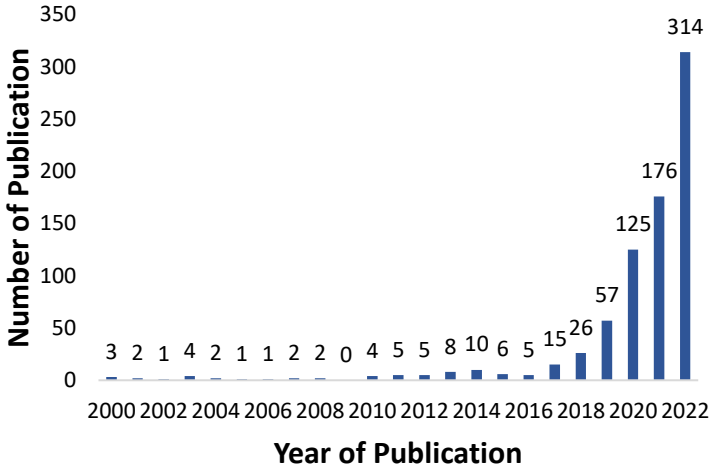

Figure 2. Distribution of Publications by Years

Figure 2 reveals that academia has started paying more attention to AI in the 2020s and afterward. During the period under consideration, there has been an exponential rise in the frequency of academic papers devoted to AI and its many applications in HE.

Distribution of Publications by Country

The examination also encompassed an analysis of the geographical distribution of publications within the field. Figure 3 comprehensively displays the ten countries with the highest publications overall.

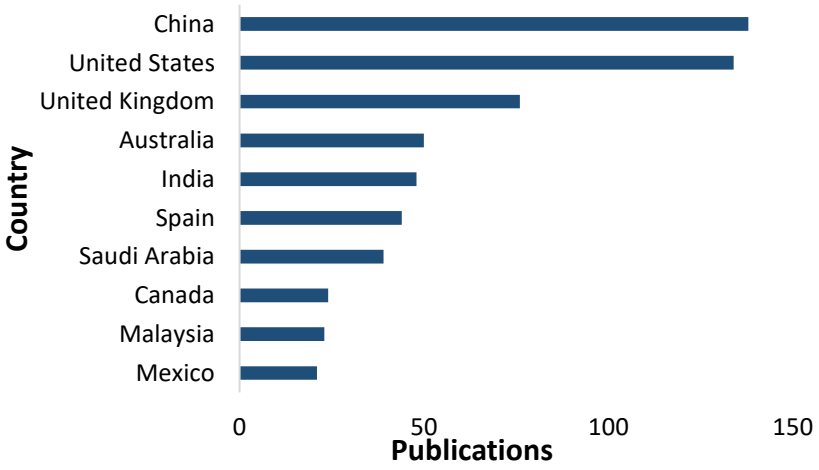

Figure 3. Distribution of Publications by Country

In Figure 3, we can see a breakdown of where countries have published AI research. China (with 138 papers) and the United States (with 134 papers) are well ahead of other nations working on AI in HE, and both rank in the top 10 countries for published research regarding AI applications. Whereas Europe has made a sizable amount (here, the United Kingdom and Spain), Africa has contributed nearly nothing. Researchers from India and Australia have also contributed significantly with their published works.

Bibliometric Findings

Journal Citation Analysis

A comprehensive citation analysis was initially performed on the journals with the most publication count in the subject area within the Scopus database. The resulting data of the top 10 journals with the most publications has been compiled and displayed in Table 1.

Table 1. Journal Distribution Based on Publications and Number of Citations

No	Journal	Number of Articles	Number of Citations	h Index	Q Value
1.	Education and Information Technologies	16	221	61	Q1
2.	International Journal of Emerging Technologies in Learning	16	194	39	Q2
3.	Computational Intelligence and Neuroscience	15	12	70	Q1
4.	Sustainability (Switzerland)	14	146	136	Q2
5.	IEEE Access	13	296	204	Q1
6.	Applied Sciences (Switzerland)	13	121	101	Q2
7.	Mobile Information Systems	12	2	42	Q3
8.	British Journal of Educational Technology	10	410	110	Q1
9.	International Journal of Educational Technology in Higher Education	10	212	49	Q1
10.	International Journal of Advanced Computer Science and Applications	10	35	35	Q3

After examining the publication distribution across different journals, it becomes clear that "Education and Information Technologies" (f=16), "International Journal of Emerging Technologies in Learning" (f=16), and "Computational Intelligence and Neuroscience" (f=15) emerged as the journals with the most frequency of publications. However, regarding the number of citations per publication, the "British Journal of Educational Technology", "IEEE Access", and "Education and Information Technologies" stand out prominently.

The Table 1 additionally included the h-Index and quartile (Q) values collected from *Scimago Journal & Country Rank* (n.d.) corresponding to the top 10 journals characterised by the most significant publication count. h- Index is a metric at the author level, primarily developed to evaluate the research quality over a period, considering both the author's scholarly productivity and the impact of their research (Schreiber, 2008). The journal "Education and Information Technologies", with the highest article count, holds a Q1 quartile value and h-Index of 61. Kluwer Academic Publishers publish the journal in the United States. Five of the ten journals mentioned have a Q1 quartile value and an h-Index above 48. Two journals, "Mobile Information Systems" and "International Journal of Advanced Computer Science and Applications", have Q3 quartile values. "IEEE Access" secures the highest h-Index value of 204. Table 1 can serve as a valuable resource for researchers aiming to publish articles on AI, specifically within the realm of education.

Publication Citation Analysis

To explore the publications with the highest citation frequency in this field, researchers compiled a list of the top 10 publications according to the citation count, as illustrated in Table 2. In bibliometrics, citation analysis stands out as a widely utilised method for evaluating the academic influence of an article within a particular knowledge domain (Hernández-González et al., 2022).

Table 2. Articles With Highest Citations

No	Title and Author (Year)	Source	Citations
1.	Learning Analytics: Ethical Issues and Dilemmas - Slade and Prinsloo (2013)	American Behavioral Scientist	442
2.	Exploring the Impact of Artificial Intelligence on teaching and learning in higher education - Popenici and Kerr (2017)	Research and Practice in Technology Enhanced Learning	288
3.	Learning Analytics Methods, Benefits, and Challenges in Higher Education: A Systematic Literature Review - Avella et al. (2016)	Journal of Asynchronous Learning Network	205
4.	Predicting the academic performance of students from VLE big data using Deep Learning models - Waheed et al. (2020)	Computers in Human Behavior	191
5.	Medical students' attitude towards Artificial Intelligence: A multicentre survey - Pinto dos Santos et al. (2019)	European Radiology	188
6.	Using Learning Analytics to scale the provision of personalised feedback - Pardo et al. (2019)	British Journal of Educational Technology	163
7.	On automated grading of programming assignments in an academic institution - Cheang et al. (2003)	Computers and Education	156
8.	A Meta-analysis of the Effectiveness of Intelligent Tutoring Systems on college students' academic learning - Steenbergen-Hu and Cooper (2014)	Journal of Educational Psychology	146
9.	A Machine Learning Approach for Tracking and Predicting Student Performance in Degree Programs - Xu et al. (2017)	IEEE Journal on Selected Topics in Signal Processing	124
10.	Predicting at-risk university students in a virtual learning environment via a Machine Learning algorithm - Chui et al. (2020)	Computers in Human Behaviour	105

Table 2 provides information on the authors and citation counts of frequently cited publications in the Scopus database from 2000 to 2022 in the field of study. According to the data, the publication by Slade and Prinsloo (2013) had the highest number of citations, totaling 442. In second and third place were the publications by Popenici and Kerr (2017) and Avella et al. (2016).

Co-Authorship Network Analysis

Bibliometric techniques for co-authorship network analysis allow precise identification of almost all aspects of scientific cooperation networks. (B. Li et al., 2023). When many authors or organisations officially acknowledge their contributions to a scientific paper, it is called co-authorship (J. Wang & Kim, 2023). The network of co-authorship contains nodes representing countries (Figure 4), organisations (Figure 5), and authors (Figure 6) who are involved in collaborative authorship.

Co-Authorship Analysis – Countries

Figure 4 showcases the co-authorship analysis of countries in the field of study in publications published within the Scopus database from 2000 to 2022. Each circular shape (node) represents a country, with larger circles showing higher dominance. A line connecting two country names (link) indicates their collaboration. The link thickness and node distance signify the level of collaboration between countries. At this stage, researchers proceeded with a specific threshold level, requiring a minimum of 5 documents and at least 10 citations. Consequently, countries with just one document about this field will be included, but countries without collaborative relations will not be displayed.

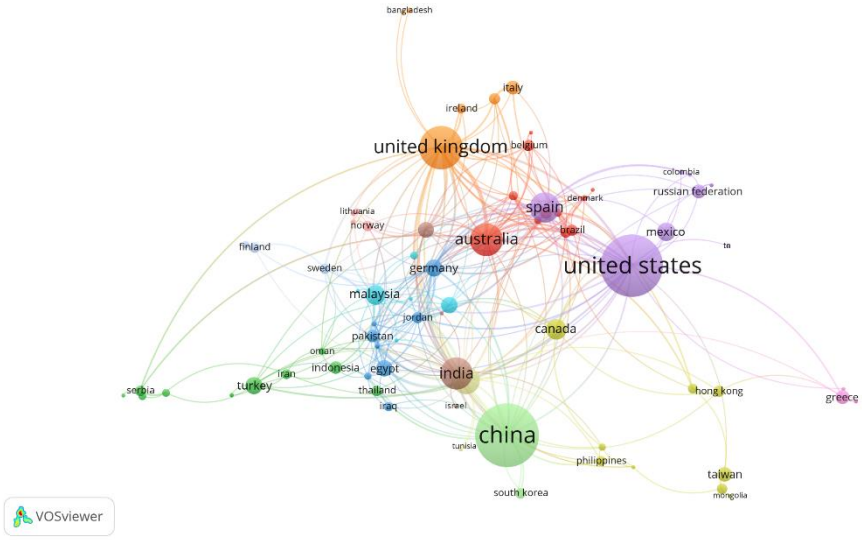

Figure 4. Network of Collaboration Among Countries

Upon analysing the country's co-authorship, it turned out that the United States and Saudi Arabia collaborated with 30 countries. In comparison, the United Kingdom collaborated with 29 countries, and China, Germany, and Australia collaborated with 24 countries. Following closely on the list were Spain (23 links), India (21 links), and others. Additionally, China (138) and the United States (134) emerge as the countries with the most significant number of publications, while the United Kingdom (2270) and the United States (2057) stand out with the highest citation counts. Furthermore, the United Kingdom (77) and the United States (61) exhibit the highest total link strength values among the countries. Continents such as Asia, North America, South America, Australia, and Europe have actively contributed by publishing documents related to the field of study. Notably, all continents except Africa have made significant research contributions. The Asian continent emerges as the most influential in this domain, having published 248 documents, surpassing the publication count of other continents.

Co-Authorship Analysis – Organizations

The network analysis of co-authorship among organisations is depicted in Figure 5. In this analysis, the researcher established a specific threshold level, requiring a minimum of 2 documents and at least 1 citation. Among the 33 organisations falling within the set threshold level, a single cluster emerged, consisting of four interconnected organisations.

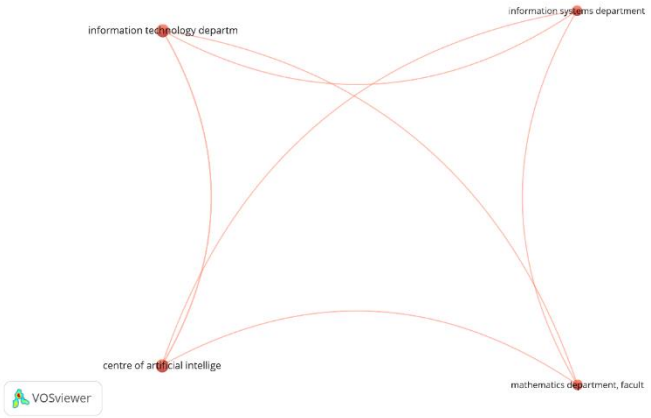

Figure 5. Network of Collaboration Among Organizations

The organisations that form the cluster were the following with three links for each: "Centre of Artificial Intelligence for Precision Medicines, King Abdulaziz University, Saudi Arabia," and "Information Technology Department, Faculty of Computing and Information Technology, King Abdulaziz University, Saudi Arabia," with three documents each. "Information Systems Department, Faculty of Computing and Information Technology, King Abdulaziz University, Saudi Arabia," and "Mathematics Department, Faculty of Science, Al-Azhar University, Egypt" with two documents each. Three of the four organisations within the cluster were from the Kingdom of Saudi Arabia.

Co-Authorship Analysis – Authors

Figure 6 depicts the analysis of co-authorship networks among authors. During this analysis, the researcher set a specific threshold level, requiring a minimum of 1 document and at least 5 citations. Among the 773 authors considered, only 365 have satisfied this threshold. Upon analysing the co-authorship of studies on the subject from Figure 6, it is evident that collaborating authors tend to publish jointly in smaller groups with three links. One example of such a collaboration is by "Habermann, R.", "Powers, J.", "Denny, J. C.", "Chen, Y.", "Wrenn, J.", "Xuh" and "Spickard, A." Additionally, most of the authors published independently.

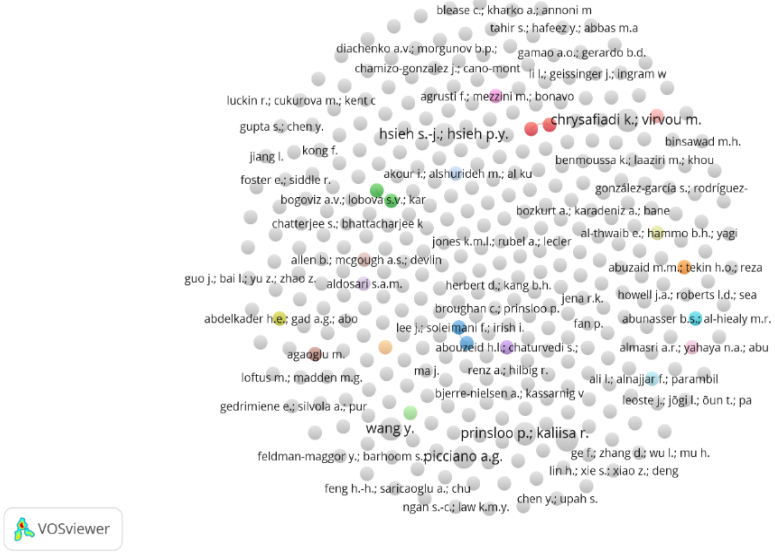

Figure 6. Network of Collaboration Among Authors

Co-occurrence Keyword Network Analysis

Figure 7 presents a visual depiction illustrating the interconnected nature of keywords. In this stage, researchers did not set a specific threshold (default threshold, minimum 5 number of occurrences of a keyword) and instead proceeded with co-occurrence analysis on all 237 keywords.

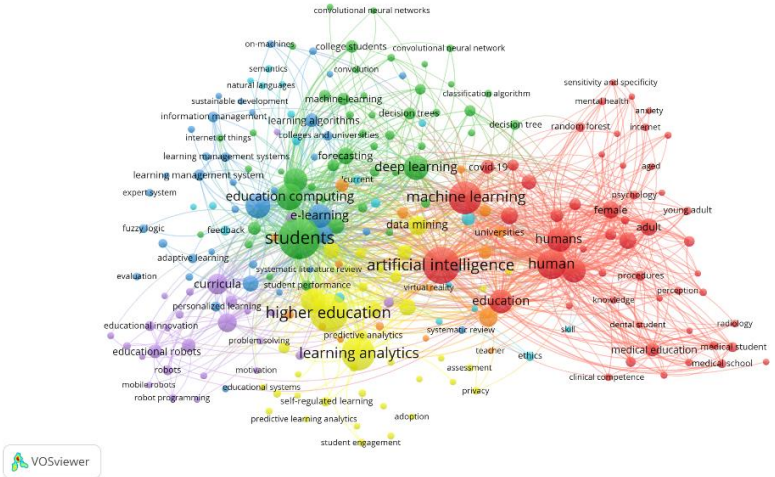

Figure 7. Network of Co-occurrence Among Keywords

The Figure 7 portrays the presence of distinct research clusters within the sphere of AI possibilities in HE. The illustration comprised seven clusters: red being the largest, followed by green, blue, yellow, violet, light blue, and orange. These clusters indicated the division of research focus into seven distinct areas. In the primary cluster (Red), characterised by the most extensive circle size, the prominent keywords were Artificial Intelligence, Machine Learning, Humans, and Education. This clustering suggests a significant interest in catalysing AI technologies to optimise the educational system and practices. Further, it focuses on developing intelligent learning systems powered by machine learning algorithms and a human-centric approach. Additionally, these keywords were grouped with other prominent keywords: Higher Education, Learning, Curricula, Learning Systems, and Students, which signifies the core research

areas within the HE context. The second cluster (Green) emphasised keywords such as Students, High Education and Deep Learning, which grouped with research on Artificial Intelligence, Curricula, Learning systems, and Higher Education. The third cluster (blue) highlighted keywords like Learning System and e-learning grouping with keywords Higher Education, Artificial Intelligence, Students, and Curricula. The yellow-coloured fourth cluster encompassed keywords such as Higher Education and Learning Analytics alongside other keywords Artificial Intelligence, Curricula, Learning Systems, and Students. In the fifth cluster (Violet), the focal keywords included Curricula, Engineering Education, and Educational Robots, in conjunction with other significant keywords, Artificial Intelligence, Higher Education, Learning Systems, and Students. This forms a distinct focus area highlighting the integration of AI, robotics and higher education for more enhanced instructional experiences and skill development among students. The sixth cluster (Light Blue) emphasised Natural Language Processing as a significant keyword, paired with Artificial Intelligence, which suggests a specialised area with an intersection of AI and NLP in HE settings. Lastly, the seventh cluster (orange) centred on keywords like Learning, University, and Artificial Neural Networks associated with Artificial Intelligence, Higher Education, Learning Systems, and Students.

The network diagram displayed in Figure 8 showcased the overlay arrangement of keyword relationships. A larger circle signifies more frequent discussions on specific topics, while the yellow regions highlight the subjects of current interest. As evidenced in Figure 8, the current subjects encompassed areas such as "Machine Learning," "Convolutional Neural Networks," "Universities," "Curriculum," and "High Education System". These emphasised topics suggest a point of prevailing focus areas in recent research discourse in the realm of AI in HE.

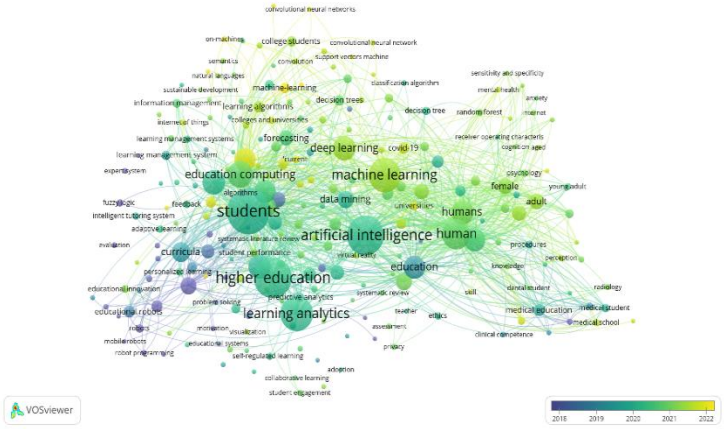

Figure 8. Keyword Co-occurrence – Overlay Visualization

Co-citation Network Analysis

Co-citation measures the relationship between items and is determined by the frequency with which they are cited together (Jeong et al., 2014). When an author and a document are cited in another article, it can indicate their proximity (Sahu, 2021).

Co-citation Analysis – Cited Authors

The Figure 9 displays the co-citation network analysis among authors. The researcher employed the default threshold of at least 20 citations per author. Among the 48786 authors included, 263 met this threshold. Gasevic, D. emerged as the author with the highest co-citation connections, accumulating a total of 24094 link strengths and 422 citations. Dawson, S. and Siemens, G. closely followed with 15621 and 12132 link strengths and 290 and 260 citations, respectively.

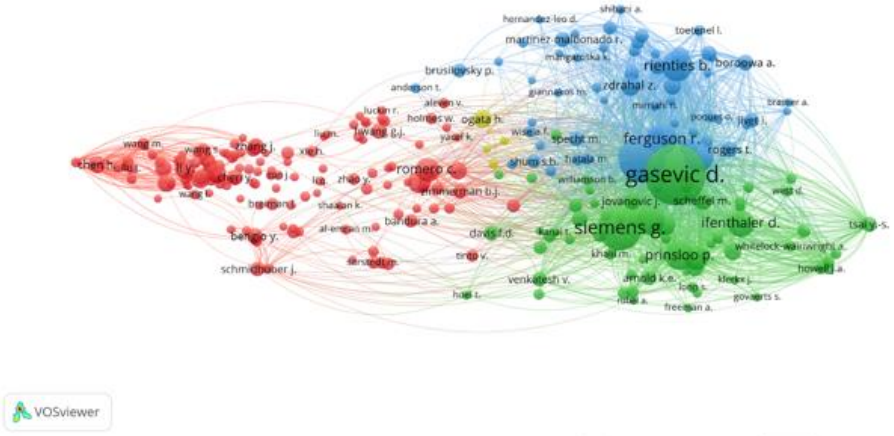

Figure 9. Network of Co-citation Among Cited Authors

Co-citation Analysis – Cited References

The Figure 10 depicts the co-citation network analysis among the cited references. The researcher utilised a specific threshold of 10 citations per cited reference. Among the 31115 authors considered, 14 met this threshold. The reference "Viberg, O., Hatakka, M., Balter, Q., Mavroudi, A., The Current Landscape of Learning Analytics in Higher Education, Computers in Human Behavior, 89, pp. 98-110, (2018)" emerged with the substantial link strength of 48. It was followed by "Siemens, G., Learning Analytics: The Emergence of a Discipline, American Behavioral Scientist, 57, 10, pp. 1380-1400, (2013)" and "Pardo, A., Siemens, G., Ethical and Privacy Principles for Learning Analytics, British Journal of Educational Technology, 45, 3, pp. 438-450, (2014)", both having a total link strength of 46 and 43, respectively.

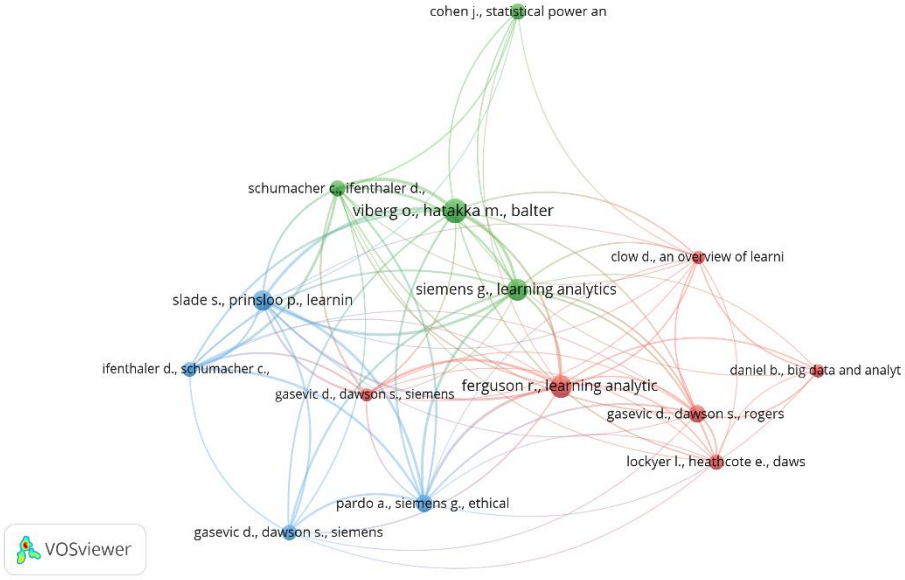

Figure 10. Network of Co-citation Among Cited References

Conclusion

This research conducted a bibliometric analysis of publications in international journals from the Scopus database, focusing on the possibilities of AI in HE from 2000 to 2022. VOSviewer 1.6.19 software was utilised for visualisation. In the last two decades, the volume of papers on AI in Education has steadily grown (Paek & Kim, 2021). The research findings also indicated a substantial growth in the frequency of publications in the study area, from 3 in 2000 to 314 in 2022 (Jatobá et al., 2019). China and the US wield the most notable influence, outpacing other nations in their contributions to this field, similar to the observations made by Crompton and Burke (2023). Moreover, as per the Congressional Research Service (2022) fact sheet on global research and development expenditures, the US held the top spot in R&D, but during the past two decades, China has noticeably closed the R&D spending gap with the US. Both countries and other nations were experiencing a surging demand for Artificial Intelligence (AI) in education due to increasing investments from private and public sectors in AI and EdTech (Williamson & Komljenovic, 2023) and the

growing appeal of edutainment. Although the complete outcomes of AI advancement may not be entirely predictable at present, it is conceivable that AI-powered applications will be among the leading educational technologies for the upcoming two decades (Roll & Wylie, 2016). Furthermore, AI-based resources and services can extend a great deal of promise to help educators, learners, and administrators at every stage of their educational journey.

While analysing the distribution of publications in the study field, two prominent journals emerged: "Education and Information Technologies" with a Q1 Quartile value and "International Journal of Emerging Technologies in Learning" with a Q2 Quartile Value. Noteworthy journals with high citation count per publication included "British Journal of Educational Technology," "IEEE Access," and "Education and Information Technologies," all with Q1 Quartile values. These journals hold significance in the domain of technology applications in education. They also serve as impactful platforms for disseminating influential research on technology in education, likely to gain attention because of their rigorous standards and contributions.

Upon analysing the citations of the most influential authors, "S. Slade" and "P. Prinsloo" stood out. Their work is published in the "American Behavioral Scientist" journal, boasting an impressive h-index of 125 and holding a Q1 quartile in the field of Education since 2014. Further, of the ten prolific authors who contributed the most in this area, four were from the United Kingdom, while two were from the United States, emphasised the significance of these countries in this particular domain (Cath et al., 2018).

Co-authorship analysis across countries showed an interesting pattern in international collaboration within the study field. The collaborative networks of the US and Saudi Arabia with 30 countries, the UK with 29, and China, Germany, and Australia with 24 countries spotlight extensive international partnerships in this domain. By fostering diverse ideas and solutions, this global collaboration strengthens AI-driven HE across borders. Remarkably, all continents except Africa have made significant research contributions in this area. The promotion and use of modern technologies, including AI, in Africa still need to improve due to emerging challenges, including the lack of technical expertise, discrepancy, unstructured data, absence of government policies, ethical concerns, and user attitudes (Okolo et al., 2023). As for the co-author analysis of the relevant literature on the study area, most authors published independently, with only a small group found to be published jointly. As the most rapidly evolving field garnering global attention, it is crucial to establish collaboration among authors and organisations guided by agreed democratic principles to yield more advantageous results.

The co-occurrence analysis revealed that the prominent keywords were Artificial Intelligence, Machine Learning, Humans, and Education, which form the primary research focus concerning the other prominent keywords, Higher Education, Learning, Curricula, Learning Systems and Students. The current subjects in the field were "Machine Learning," "Convolutional Neural Networks," "Universities," "Curriculum," and "High Education System". Artificial Intelligence was connected with all the clusters. It is predicted that in the modern world of data computing, Machine Learning is essential for offering programs the capacity for intelligent performance (Sarker et al., 2021). For example, using ML algorithms, Gray and Perkins (2019) developed an efficient retention prediction model, which has proven successful in facilitating learning. These clusters outline diversified research fields and contribute to a thorough investigation of how AI transforms higher education across multiple domains. In the co-citation network analysis, Gasevic, D. emerged as the author with the highest co-citation connections and the reference "Viberg, O., Hatakka, M., Balter, Q., Mavroudi, A., The Current Landscape of Learning Analytics in Higher Education, Computers in Human Behavior, 89, pp. 98-110, (2018)" emerged with highest co-citations. This indicates that the particular study on the learning analytics landscape in HE has been widely cited and is regarded as significant in the scholarly discussion on AI in HE.

The comprehensive bibliometric analysis showed substantial growth in publications within the field of AI in HE, implying a remarkable unfolding from 2000 to 2022. Notably, the study highlighted the dominant influence of China and the US in publications, signifying their impactful role in transforming the field of study. Further, the journal with the most publications and citations on AI in HE was found to hold the Q1 rank with 16 articles and 410 citations, which signifies the rising prevalence of AI in HE scholarly outputs. The emergence of new themes in this field, like Machine Learning, Convolutional Neural Networks, Universities, Curriculum, and High Education Systems, co-occurring with the prominent keyword AI, reflects the evolving landscape of AI in HE with the advancement in novel AI technologies. These findings, along with bridging the substantial knowledge gaps, prompt further investigation into the rapidly evolving HE circumstances in light of upcoming technological breakthroughs. Moreover, the study underscores the need for more global cooperation in the field for shared advantages and advancements. Additionally, by emphasising new themes, publications' profile outputs, and influential countries in the field of AI in HE, the study paves the way for future research. Thereby, it encourages scholars to delve into complex interconnections and unresolved queries, ultimately shaping novel paths within this evolving domain. The study, in total, addresses the interconnections between the emerged novel AI themes comprehensively and is oriented more directly over the emerging domains of HE in an era where it has been treated as a market term rather than a social term with surplus funding like trade, machinery and e-commerce flows which changing its primary prospects from classrooms to virtual media.

The study suggests that other researchers can use these findings to create scientific publications about the prospective applications of AI in HE. Furthermore, there is room for further research on this topic to enhance bibliometric mapping in the field. This can be achieved by incorporating more sources and databases, utilising other bibliometric analysis software like BibExcel, CiteSpace, and HistCite, and exploring other writing formats such as proceedings, review papers, and book chapters.

The present study has some limitations. The study summarised published studies on AI in HE from 2000 to 2022, using data sourced primarily from the Scopus database as of July 9th, 2023, and focused exclusively on English journals. Notably, this analysis excluded post-date publications and journals in other languages, possibly leading to minor variations. Additionally, it did not include papers, books and book chapters in the field, which suggests future research opportunities.

Authorship Contribution Statement

The four authors made significant contributions to the article's conceptualization, design, collection, and analysis of the data. The article's theme and structure were conceptualised by the first author and the corresponding author, Kavitha and Joshith. After the acquisition of the data set, screening, validation, and the sequential presentation of the data was done by Kavitha, & P Rajeev, the third author. Analysis of the final data after the exclusion based on the criteria was done by Kavitha. Interpreting the data results and finding the literature towards discussion was done by the fourth author, Asha S. The initial draft of the work was written by Kavitha and Joshith provided suggestions and corrections on the draft. After the final discussion with all the four authors, the compilation of the article was done by Kavitha and Joshith approved the final manuscript.

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