Artificial Intelligence in Higher Education: A Decade of Research Insights Through Bibliometric Analysis

F. Sehkar Fayda-Kinik[a]
School of Foreign Languages, Istanbul Technical University, Turkey

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Abstract: This study aims to examine the key research characteristics of artificial intelligence (AI) in higher education (HE), identify major collaborative networks, and highlight the main AI research trends and topics over the past decade. Adopted as a bibliometric analysis on AI research in HE between 2014 and 2024, the relevant literature was retrieved from the Web of Science (WOS) in November 2024. After the publications obtained from initial screening (n=37,545) on the WOS were eliminated based on the application of the predetermined inclusion/exclusion criteria, 2,195 eligible documents were analyzed for their main characteristics, collaborative networks, research trends and topics on VOSviewer. According to the results, a significant upward trend has been found with a particular acceleration in both publications and citations since 2014. Collaboration trends clarified distinct clusters of research activity, with Europe, English-speaking countries, and Latin America forming strong intra- and inter-regional networks. Keyword clustering analysis further demonstrated research priorities, with core areas such as AI concepts, data analytics, and educational strategies whereas topics like academic ethics, security, and robotics are still emerging in the field.

1 INTRODUCTION

Artificial intelligence (AI) can be defined as computing systems capable of engaging in human-like processes including cognitive functions such as learning, adapting, synthesizing, problem-solving, and using data for complex processing tasks (Baker & Smith, 2019; Popenici et al., 2017). In higher education (HE), AI applications cover a range of areas in which academic and administrative functions can be enhanced. For instance, AI technologies support personalized learning through adaptive systems that adjust educational content to student needs and offer customized feedback via intelligent tutoring systems (Mehrfar et al., 2024; Zhang, 2023). Moreover, predictive analytics is used to forecast student outcomes, which helps institutions make data-driven decisions to improve student success (Chu et al., 2022; Murdan & Halkhoree, 2024). Additionally, AI facilitates administrative efficiency by automating routine tasks like admissions and resource management and allows staff to focus on more complex responsibilities (Rahardjo et al., 2024; Shimpi, 2024). Furthermore, virtual assistants and chatbots provide instant support and improve accessibility and engagement for students (Wenge, 2021; Shimpi, 2024). Because of all these enhancements in the areas affecting organizational practices, AI technologies have become prominent to be seriously evaluated in favor of students, faculty, and staff in HE.

The integration of AI technologies into HE settings has substantially escalated in recent years. AI has started to transform multidimensional aspects of academia including teaching, learning, and administrative processes (Crompton & Burke, 2023) along with research activities (Al-Zahrani, 2023). In other words, AI technologies facilitate institutional and academic processes including decision-making, research, and learning experiences for students, faculty, and staff because of their capabilities to analyze information and large datasets for overall academic operations in HE (Téllez et al., 2024; Zahid et al., 2024). However, AI use brings about a complicated web of potential opportunities as well as challenges that necessitate careful consideration and academic research (Leoste et al., 2021). For example, ethical concerns are frequently raised about data

[a] https://orcid.org/0000-0001-6563-4504

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privacy, algorithmic bias, and academic integrity within the practices in HE (Al Daraai et al., 2024; Cotton et al., 2024; Ghandour, 2024).

Despite the wide range of inclusive and capacity-enhancing functions that AI technologies offer for practices in universities, there are still ongoing risks and ethical issues with undefined borders related to the use of AI in HE. A critical evaluation of AI research in HE is necessary to enhance its contribution to HE activities, follow the impact of the latest AI-focused developments in educational settings as well as determine the boundaries of problematic areas to provide the necessary guidance for all the stakeholders. Therefore, this study aims to examine the key characteristics of AI research in HE, identify major collaborative networks, and highlight the main research trends and topics over the past decade.

2 METHODS

2.1 Research Design

This study was designed as a bibliometric analysis of AI research in HE between 2014 and 2024. Bibliometric analysis is a quantitative method used to evaluate and analyze the literature in a specific field, and it involves statistical and mathematical techniques to bibliographic data obtained from certain databases to uncover patterns and trends in scientific research (Carlos et al., 2024; Marvi & Foroudi, 2023). Accordingly, the following research questions (RQs) were investigated:

RQ1. What are the descriptive characteristics of AI research in HE over the past decade?

RQ2. What are the major collaborative networks in AI research in HE over the past decade?

RQ3. What are the main AI research trends and topics in HE over the past decade?

2.2 Data Collection

To address the RQs with a bibliometric analysis, a number of steps were carried out to determine the eligible publications. First, the keywords were specified for AI (e.g., smart technologies, machine learning, deep learning, adaptive systems, neural network, cognitive computing, robotics, intelligent systems, chatbots, automated systems, algorithmic systems, intelligent systems, data mining, learning analytics, predictive analytics, language processing) and HE (e.g., university, tertiary education, college, undergraduate, post-graduate). Subsequently, the search string was formulated using the specified keywords with their equivalences. The Boolean operators (e.g., AND, OR) were integrated properly into the search string.

To identify the AI studies in HE, the database was selected as the Web of Science (WOS) because it is a widely recognized and credible source for academic research involving comprehensive and high-quality publications with advanced filtering options. Thereafter, the search string was applied to retrieve the relevant literature on the WOS in November 2024.

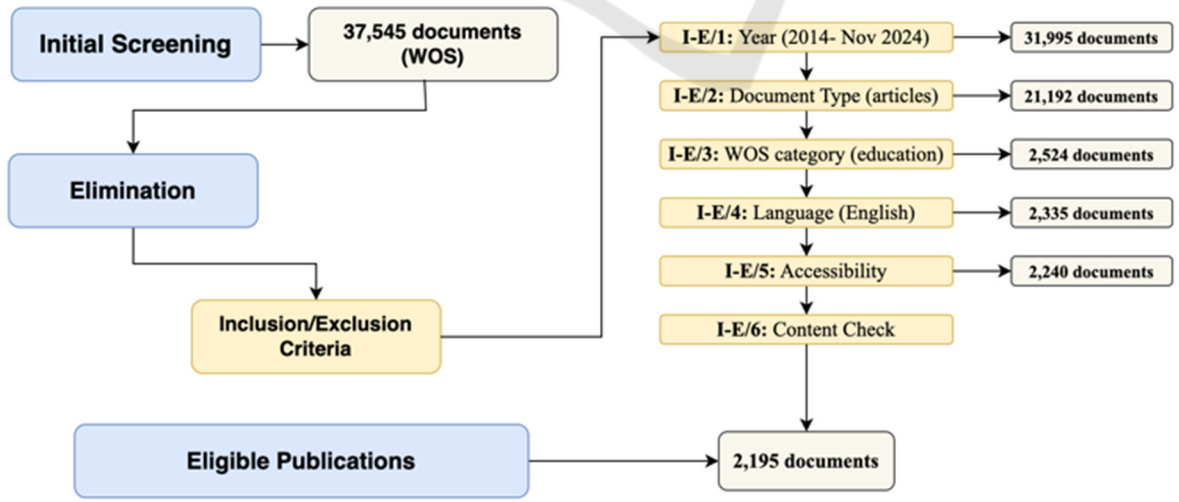

Figure 1: Flowchart of source eligibility.

After initial screening, the inclusion/exclusion (I-E) criteria were implemented to obtain eligible studies. In this respect, I-E/1, I-E/2, I-E/3, and I-E/4 were automatically applied on the WOS platform, but I-E/5 and I-E/6 were manually carried out by the researcher, as demonstrated in Figure 1.

A systematic process for the identification of eligible publications was performed to refine the initial dataset from the WOS (n=37,545). Accordingly, the first criterion (I-E/1) limited documents published between 2014 and November 2024 (n=31,995). The second criterion (I-E/2) included only articles, excluding other document types (n=21,192). Next, the studies were restricted to those within specific WOS categories (I-E/3); namely, education, educational research, and education scientific disciplines (n=2,524). The language criterion (I-E/4) further limited the dataset to the articles written in English (n=2,335). Subsequently, based on the accessibility criterion (I-E/5), the documents lacking the necessary components for bibliometric analysis (e.g., missing keywords or abstracts) were excluded (n=2,240). Finally, the content of the publications was checked (I-E/6) depending on the scope of the research, and 2,195 eligible publications were obtained for further analysis.

2.3 Data Analysis

To investigate the eligible sources based on the RQs, VOSviewer was used to perform the analyses compatible with bibliometrics. Firstly, citation and impact analyses were carried out to identify the distribution of the eligible publications (n=2,195) among countries and institutions along with annual trends to reveal the descriptive characteristics of AI research in HE (RQ1). Additionally, frequency analyses were performed to detect the top 10 countries with the most influential studies and the highest number of publications. Then, to determine how researchers and institutions in different regions cooperate and which regions have stronger cooperation (RQ2), co-authorship analysis was conducted, and cooperative networks were created between authors and institutions, which depicts the nature of international cooperation in AI research in HE. Moreover, density analysis was performed to detect the publication activities of institutions. Finally, keyword clustering analysis was conducted along with frequency and proximity analyses of keywords in the eligible documents to identify the main AI research trends and topics in HE and how they have evolved over time (RQ3). Based on the results, a network map was created for the thematic distribution of keywords with a density and centrality map of keyword categories. The visualizations were generated as an output of VOSviewer, and Phyton was used in the production of the density and centrality map.

3 RESULTS

3.1 Descriptive Characteristics of AI Research in HE

To address RQ1, the descriptive features of 2,195 publications were investigated in terms of the annual distribution of the documents with their citations, the top 10 countries contributing to AI research in HE, the most influential institutions, and the top 10 impactful AI studies. First, the annual distribution of the eligible articles was analyzed by number as demonstrated in Figure 2. The distribution of 2,195 AI publications in HE indicated an upward trend in the last decade from 2014 to 2024. In 2014, 42 documents were published and received 1,920 citations. The number of documents and citations gradually increased until 2018, when 99 documents were published and these documents received a total of 4,040 citations. In 2019, this trend escalated to 152 documents with 6,101 citations. In 2020, a significant increase was observed with 182 documents receiving 8,095 citations. In the following years, this upward trend continued in terms of both publications and citations and reached its peak in 2023 with 423 publications and 20,965 citations. In 2024, even though the data was limited to the ones published until November, it was observed that the most studies and dramatically high impacts were identified in this year with 563 publications and 30,215 citations.

Subsequently, the top 10 countries having contributed to AI research in HE in the last decade were analyzed based on the number of documents and citation rates. The results are displayed in Figure 3.

Accordingly, the USA contributed to AI research in HE at the highest rate with 369 studies and 4,498 citations. China ranked second with 274 articles and 2,772 citations. Australia ranked third with 205 studies and 3,291 citations, followed by England with 157 documents and 2,301 citations, and Spain with 123 articles and 1,191 citations. The remaining countries are listed in the 70-76 publication range: Canada, Taiwan, South Africa, Turkey, and Germany. Among these countries, the highest citation rates were identified in Taiwan and Turkey with 1,368 and 1,256 citations respectively.

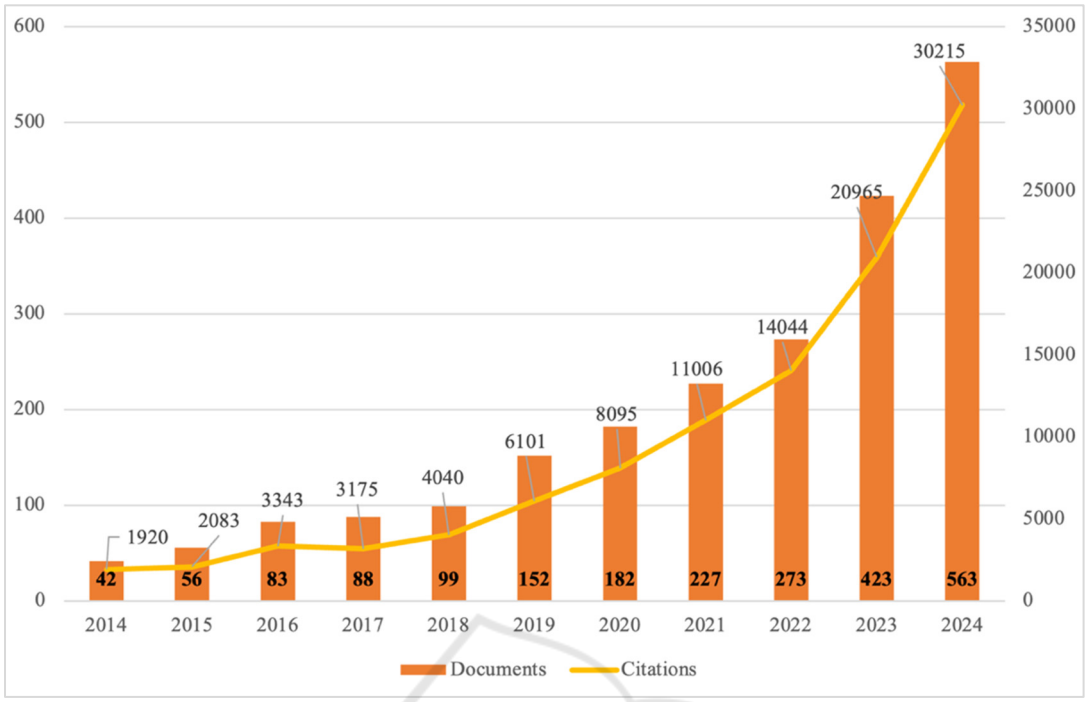

Figure 2: Annual distribution of AI research in HE by number and citations over the past decade

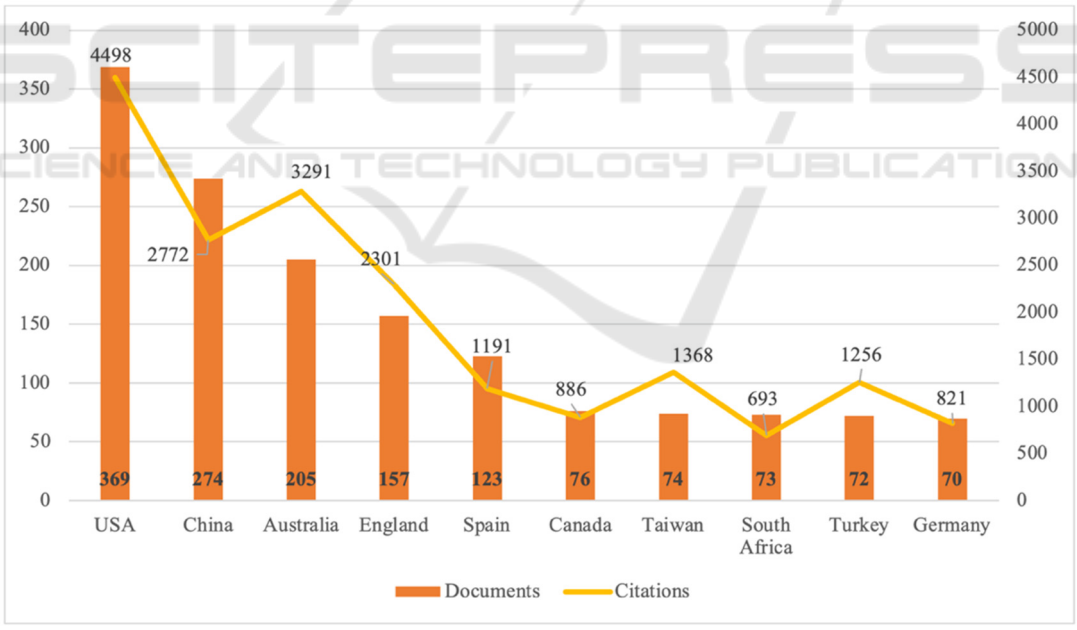

Figure 3: Top 10 countries contributing to AI research in HE over the past decade.

Next, the most influential institutions in the field were investigated in the last decade. Accordingly, these institutions are presented with their country, document and citation numbers, and total link strength in Table 1. The metric of total link strength was selected to analyze the extent and intensity of relationships in more depth because it takes into account not only the number of links an organization has with other organizations but also the strength of these links. Alternatively, links could only be used to show how many different organizations are connected to one organization. However, this metric

Table 1: Most influential institutions in AI research in HE over the past decade.

Organization	Country	Documents	Citations	Total Link Strength*
University of Edinburgh	Scotland	24	1,380	357
Monash University	Australia	40	925	321
University of South Australia	Australia	18	682	168
Open University	United Kingdom	34	786	145
University of Sydney	Australia	19	588	135
University of Belgrade	Serbia	8	515	124
Curtin University	Australia	16	423	113
Universidad Carlos III de Madrid	Spain	7	177	99
Murdoch University	Australia	7	176	83
Pontificia Universidad Católica de Chile	Chile	11	161	81
University of Queensland	Australia	26	275	81
Tallinn University	Estonia	5	105	77
King Abdulaziz University	Saudi Arabia	10	84	74
Deakin University	Australia	13	285	73
University of Mannheim	Germany	10	285	72

*The total link strength attributes indicate, respectively, the number of links of an item with other items and the total strength of the links of an item with other items (Van Eck & Waltman, 2022).

does not measure the intensity of links or the strength of inter-institutional cooperation, which may lead to overlooking the nature of this cooperation. Therefore, total link strength was applied to measure the total strength of the links between organizations. In this respect, the dimensions in both quantity and quality for collaborations were assessed.

In the last decade, the leading institution with the highest citation number in AI studies was found as the University of Edinburgh in Scotland, with 24 documents, 1,380 citations, and a total link strength of 357, which indicates its central role in AI research in HE. Monash University in Australia followed with 40 studies, 925 citations, and a link strength of 321. The other prominent Australian institutions were revealed as the University of South Australia, University of Sydney, Curtin University, Murdoch University, University of Queensland, and Deakin University, which emphasize Australia's significant contribution to this research area. Open University in the United Kingdom also played a crucial role with 34 articles and 786 citations. The University of Belgrade in Serbia, Universidad Carlos III de Madrid in Spain, Pontificia Universidad Católica de Chile in Chile, Tallinn University in Estonia, King Abdulaziz University in Saudi Arabia, and University of Mannheim in Germany also ranked among the most influential institutions, each contributing notably through document output, citation impact, and collaborative link strength within the academic community.

Finally, the top 10 influential studies were detected according to the impact they have created with their citations. These studies broadly focused on the impact of AI, specifically ChatGPT, and learning analytics in HE. Cotton et al. (2024) explored academic integrity issues related to ChatGPT and led with 429 citations. Gasevic et al. (2016), with 364 citations, emphasized the need for personalized learning analytics rather than a one-size-fits-all approach. Farrokhnia et al. (2024), cited 244 times, offered a SWOT analysis on ChatGPT's role in HE. You (2016) analyzed predictive indicators for online course success and contributed to the field with 233 citations. Chatterjee and Bhattacharjee (2020) reviewed AI adoption in HE and received 154 citations. Similar to Cotton et al. (2024), Perkins (2023), with 152 citations, examined academic integrity concerns around AI language models in the post-pandemic period. Pursel et al. (2016), Chan (2023), Crompton and Burke (2023), and Chan and Hu (2023) each investigated diverse aspects of AI in HE, such as student motivation, policy frameworks, and student perspectives on generative AI. Overall, all these works highlighted increasing attention to challenges and opportunities resulting from AI use in HE.

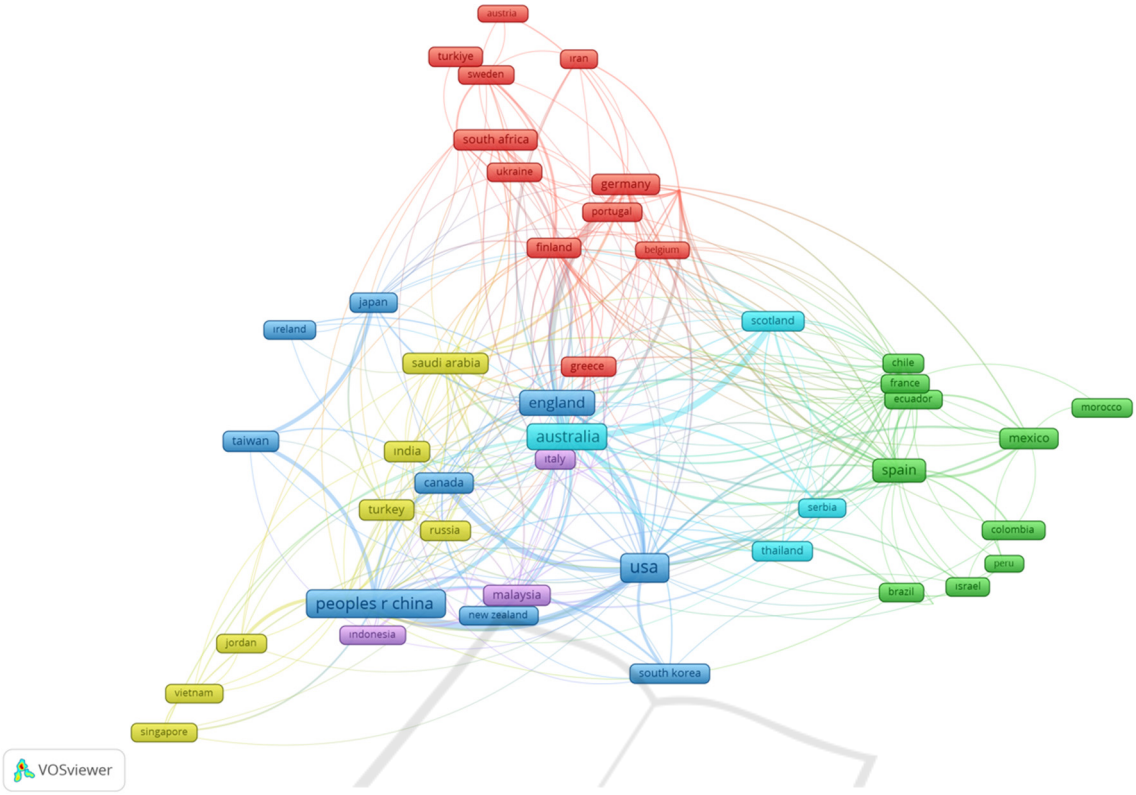

Figure 4: Country-based collaborative trends in AI research in HE over the past decade.

3.2 Collaborative Networks in AI Research in HE

The collaborative trends in the last decade were explored among 2,195 AI studies in HE in terms of the interactions of countries and institutions on VOSviewer. Therefore, co-authorship analysis was conducted to address RQ2. In Figure 4, international collaborations through AI research in HE are illustrated with the countries grouped into color-coded clusters indicating regional partnerships. Accordingly, it was revealed that the red cluster consisted mostly of European countries including Germany, Austria, and Belgium, which reflects strong intra-European collaborations. The blue cluster centered on English-speaking countries such as the USA, England, and Australia, and the USA served as a major global hub strongly linking with China. The green cluster featured Latin American and European nations like Spain, Mexico, and Brazil, which highlights the transatlantic link in the field. Finally, the yellow cluster represented regional collaborations within Asia, where countries are working closely on AI research in HE.

Subsequently, the networks among the institutions contributing to AI research in HE were revealed through a density analysis on VOSviewer. Figure 5 demonstrates the findings obtained from the density analysis of institutions having published at least five papers on AI research in HE in the last decade. In the map created as a VOSviewer output, color intensity was used to indicate areas of high research activity, and brighter areas were represented by clusters of institutions having high volumes of publications. The key institutions were identified as Monash University, the University of Edinburgh, Tecnológico de Monterrey, and the University of Queensland for their strong contributions to the field. Other universities in Australia, the UK, China, and the USA also formed notable clusters, which highlights the intensive AI research efforts in HE in these regions.

3.3 AI Research Trends and Topics in HE

As a final step, RQ3 was investigated to reveal the AI research trends and topics in HE. Accordingly, keyword clustering analysis along with frequency and proximity analyses of keywords were carried out on VOSviewer. In this respect, keyword co-occurrence analysis was conducted on author keywords used at

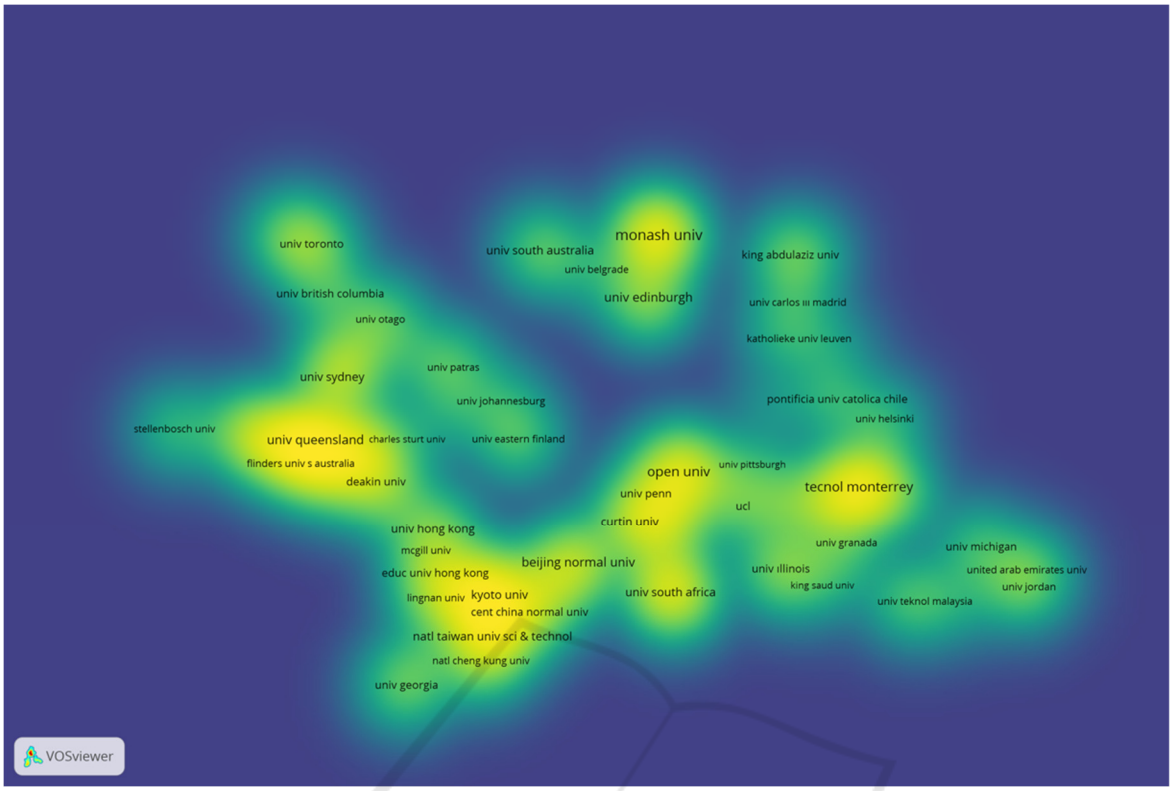

Figure 5: Institution density map with high-frequency AI studies in HE over the past decade.

least 10 times in AI research in HE. The results are displayed as a networking map of the keywords in Figure 6. The map visualizes keywords as nodes, with connections between them indicating co-occurrence relationships. Each color represents a distinct thematic cluster that groups the keywords based on their usage patterns and associations.

The red cluster focused on foundational AI terms like "artificial intelligence" and "machine learning" with the concepts tied to technical applications. The green cluster emphasized educational methodologies and specific learning strategies, such as "active learning" and "collaborative learning". The purple cluster included learning analytics, which indicates a focus on data-driven approaches to understanding educational outcomes. The yellow cluster represented the topics in educational technology and online learning, with terms like "e-learning" and "distance education". The blue cluster featured the keywords linked to student engagement and instructional practices including "assessment" and "feedback" as the key concepts.

Next, author keywords in AI research for HE were categorized into distinct themes with their occurrence counts representing the frequency (*f*) of each theme as listed in Table 2. The most prominent category was detected as "artificial intelligence and related concepts" (AlaRC) which appeared 914 times, including terms like AI, machine learning, deep learning, and natural language processing. "Data analytics in education" (DAiE) followed with 630 occurrences, featuring keywords such as data mining and learning analytics. "Higher education" (HE) was found another significant category and appeared 447 times. The categories of "types of education" (ToE) (*f*=288), which included online learning and e-learning, and "learning approaches and strategies" (LAaS) (*f*=190), with terms like active learning and collaborative learning, further diversified the research focus on AI in the last decade.

Finally, keyword clustering analysis was performed on VOSviewer to reveal the density and centrality of the distribution of keywords according to their categories in AI research in HE, as illustrated in Figure 7.

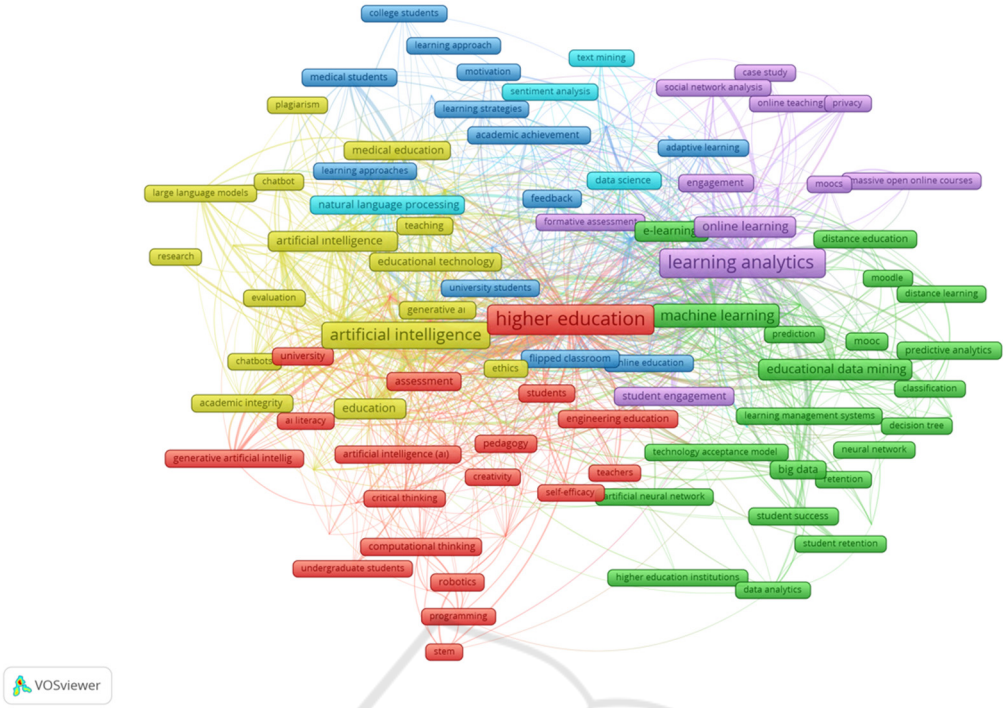

Figure 6: Keyword co-occurrence map of high-frequency keywords in AI studies in HE over the last decade.

Table 2: Author keywords in thematic groups.

Merged Category	*f*	Keywords in the Merged Category
Artificial Intelligence and Related Concepts	914	Artificial intelligence (AI), AI literacy, artificial neural network, deep learning, machine learning, Generative AI, large language model/s, natural language processing, big data, data science, computational thinking, chatbots, decision tree, programming, random forest, augmented reality
Data Analytics in Education	630	Data analytics, data mining, educational data mining, predictive analytics, sentiment analysis, social network analysis, text mining, learning analytics
Higher Education	447	Higher education
Types of Education	288	Online education, online learning, distance education, distance learning, e-learning, blended learning, flipped classroom, flipped learning, massive open online courses (MOOC/s)
Learning Approaches and Strategies	190	Learning, learning approach/es, learning strategies, active learning, adaptive learning, collaborative learning, experiential learning, project-based learning, personalized learning, surface learning
ChatGPT	158	ChatGPT, chatbot
Evaluation in Education	102	Assessment, evaluation, formative assessment, feedback
Learning and Teaching Design	101	Curriculum, curriculum design, learning design, course design, pedagogy, learning outcomes
Academic Ethics and Security	94	Academic integrity, ethics, privacy, plagiarism, equity
Student Types	88	College students, university students, undergraduate students, medical students, students
Academic Success and Performance	80	Academic achievement, academic performance, student performance, student success
Social Media and Interaction	78	Social media, student engagement, engagement
Technology and Educational Technology	71	Technology, educational technology, technology acceptance model
Research and Methodology	64	Prediction, classification, research, case study, qualitative research
Learning Management Systems	36	Learning management system/s, Moodle
Robotics and Innovation	36	Educational robotics, robotics
Others	604	Keywords that cannot be assigned to any category

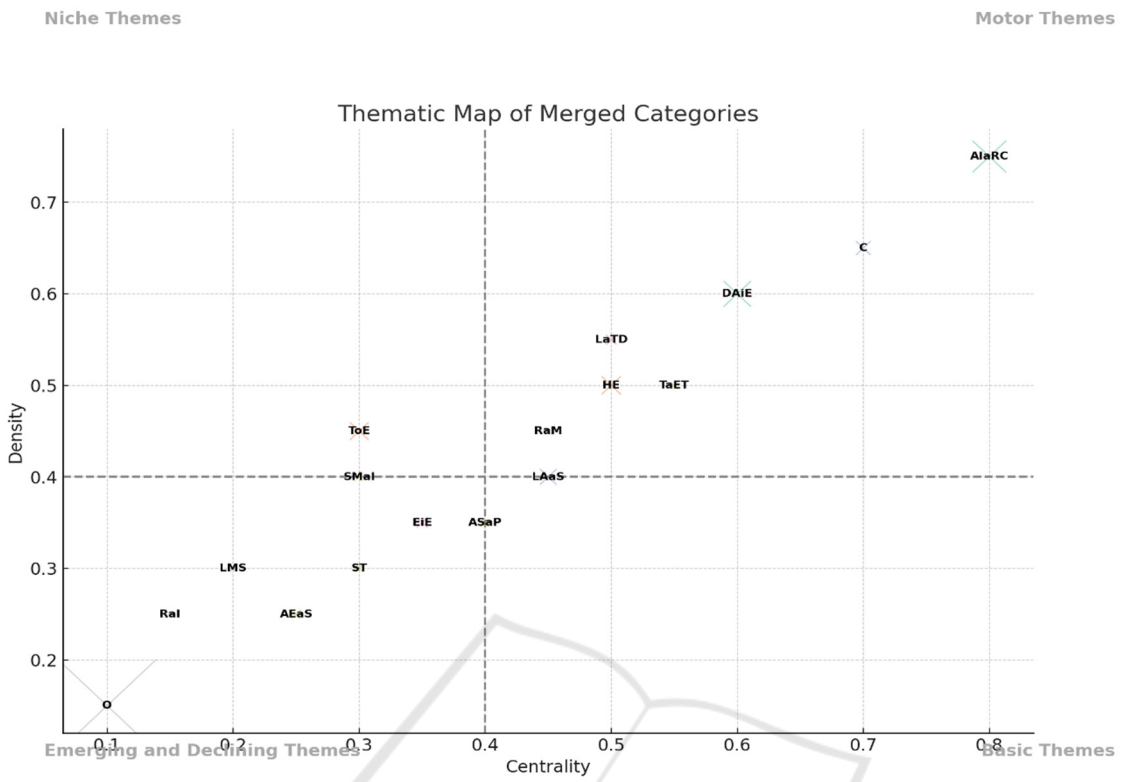

Figure 7: Thematic map of keyword categories by density and centrality*.

***AlaRC**: Artificial Intelligence and Related Concepts, **DAiE**: Data Analytics in Education, **HE**: Higher Education, **ToE**: Types of Education, **LAaS**: Learning Approaches and Strategies, **C**: ChatGPT, **EiE**: Evaluation in Education, **LaTD**: Learning and Teaching Design, **AEaS**: Academic Ethics and Security, **ST**: Student Types, **ASaP**: Academic Success and Performance, **SMaI**: Social Media and Interaction, **TaET**: Technology and Educational Technology, **RaM**: Research and Methodology, **LMS**: Learning Management Systems, **RaI**: Robotics and Innovation, **O**: Other

Accordingly, the keywords with high centrality and high density are presented in the upper right corner of the map as motor themes, and these are the categories of "artificial intelligence and related concepts" (AlaRC), "ChatGPT" (C), and "data analytics in education" (DAiE). These categories indicated that studies on AI use in education have been concentrated and widely investigated in the field over the last decade. "Robotics and innovation" (RaI) and "academic ethics and security" (AEaS) are located in the lower left corner of the map with low centrality and low intensity as emerging themes, which suggests that AI studies in this field have been limited or new over the last decade. Particularly, the concept of "robotics and innovation" (RaI) was analyzed with its context as depicted in Figure 8.

While "robotics" represents a field associated with robotic technologies and engineering processes in general, "educational robotics" emphasizes the applicability of these technologies in the educational context and their integration into pedagogical practices. Both concepts have a strong connection with technical skills such as STEM, "computational thinking" and "programming", which implies that robotics applications are a critical tool for the development of digital skills in HE. In addition, the theme of "educational robotics" is directly associated with pedagogical concepts such as "pedagogy", "curriculum", and "project-based learning", which shows that these technologies are not only used for knowledge transfer but also support student-centered, collaborative, and experiential learning processes.

4 DISCUSSION

In this bibliometric review, the key characteristics of AI research in HE and major collaborative networks were investigated along with the main research trends and topics in AI within HE settings. The findings of this study revealed a significant upward trend in AI research over the past decade, with a particular acceleration in both publications and citations since 2014. The growing interest in AI has been proven as

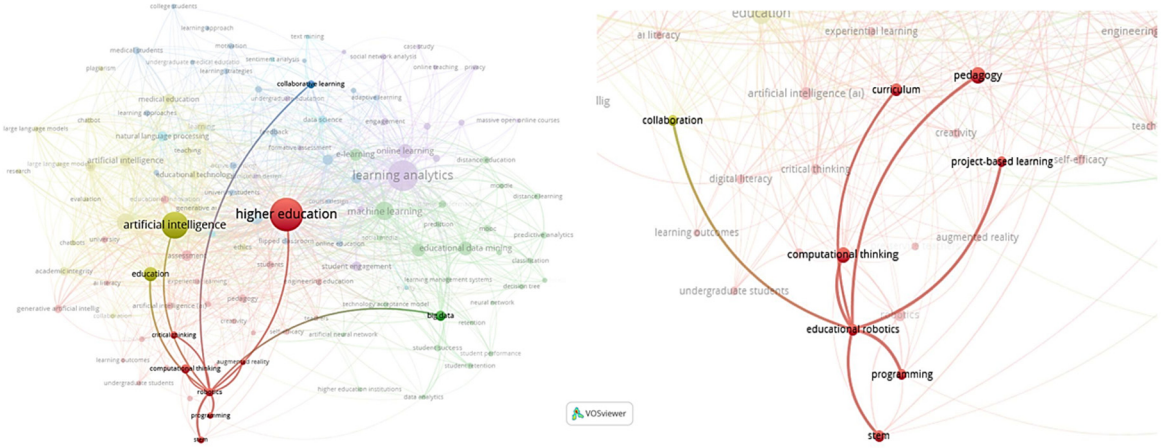

Figure 8: Keyword co-occurrence map of robotics and educational robotics.

a transformative tool in HE, especially after 2018. Consistently, Al-Zahrani (2023) confirmed its revolutionary impact on academic research. By 2023, AI-related publications and citations peaked because of the rapid advancements in AI technologies like ChatGPT and learning analytics, which have drawn substantial academic attention (Farrokhnia et al., 2024; Gasevic et al., 2016; Perkins, 2023). The yearly growth has indicated the broadening acceptance and application of AI in HE (Chan & Hu, 2023); notably, its potential to reshape educational practices and outcomes is reflected in academic research in the field.

The analysis of country-based contributions to AI research showed that the USA has become the leader in AI research in HE in the last decade, followed by China, Australia, England, and Spain. Moreover, high citation rates were reported in Taiwan and Turkey, which indicates impactful research despite their fewer publications compared to the top contributors. This geographic distribution in AI research revealed the expertise in specific regions with strong contributions from both English-speaking and non-English-speaking countries. Regarding AI integration into HE systems, each country's unique educational needs and policy environments contributed to the depth of AI research conducted in different contexts (Chan, 2023). Distinct clusters of AI research activity proved a collaborative global effort including strong intra- and inter-regional networks in HE. Similarly, Hu et al. (2020), in their network analysis concerning AI between 1985 and 2019, confirmed the significant level of international collaboration in AI research.

AI research priorities were identified as AI concepts, data analytics, and educational strategies by the keyword clustering analysis. AI in education is still predominantly focused on foundational concepts and data-driven educational improvements (Crompton & Burke, 2023; Guo et al., 2024; Paek & Kim, 2021). However, topics like academic ethics, security, and robotics were detected as emerging themes in AI research. Consistently, Guo et al. (2024), in their bibliometric review on AI in education between 2013 and 2023, identified educational robots and large data mining as emerging topics.

5 CONCLUSION

AI technologies have been transforming HE systems in a groundbreaking and unprecedented way. This transformation can be realized substantially with AI research. Emerging AI applications should be evaluated in a way that will increase the scope and quality of the functions of universities, and possible risks resulting from AI tools should be analyzed, and necessary guidance should be provided beforehand. In this respect, policymakers and educational administrators are recommended to reconsider that AI research should be supported by the development of global collaborations and the allocation of resources to these studies.

This study is limited to the research indexed in the WOS database between 2014 and 2024 even though this approach ensures a high level of academic rigor and relevance. The potential publications in the other platforms can be included in further research to expand the scope of findings in AI research. Besides, the selected keywords can be diversified to obtain more interpretively extensive results; thus, a wider range of perspectives and emerging trends in AI research can be captured within HE.

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