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Research Article

Mapping the Knowledge Landscape of AI in Higher Education: A SWOT Analysis

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ABSTRACT

This study uses bibliometric and visualization analysis to explore the publication landscape of Artificial Intelligence (AI) in Higher Education, aiming to uncover new insights and trends. By utilizing bibliometric analysis to identify the strengths, weaknesses, opportunities, and threats within the literature on AI in higher education. Analyzing 330 peer-reviewed papers published on Scopus between 2017 and September 2023, the research provides an overview of AI research trends in higher education. The findings from this study highlight strengths, weaknesses, opportunities, and threats (SWOT) of the knowledge landscape of AI in Higher Education. The study reveals a significant increase in publication growth in 2023, reflecting a growing interest in AI adoption and its impact on education. However, potential biases and disparities exist, with the majority of studies originating from the Global North. The analysis shows opportunities for AI to revolutionize education but also emphasizes ethical concerns and challenges related to AI adoption. The visualization of this analysis offers insights into the complex relationships and patterns within the AI publication landscape, providing valuable guidance for researchers, policymakers, and educators seeking to leverage AI advancements in higher education.

Keywords: Bibliometric analysis, ChatGPT, Educational Technology, Generative AI, Higher education, Impact, SWOT analysis.

INTRODUCTION

The use of artificial intelligence (AI) generative tools was brought into the spotlight following the release of Open AI's Chat Generative Pre-Trained Transformer (ChatGPT) in November 2022 (Sohail, Farhat, Himeur, Nadeem, Madsen, Singh, Atalla, & Mansoor, 2023; Stojanov, 2023). ChatGPT is a large language model (LLM) that uses publicly available content to generate human-like texts (Eke, 2023; Su & Yang, 2023). It can engage in conversations with a user and produce convincing responses that may not necessarily be based on facts (Baidoo- Anu & Ansah, 2023; Cascella, Montomoli, Bellini, & Bignami, 2023).

Although the history of generative AI can be traced back to the 1960s (Dwivedi, Kshetri, Hughes, Slade, Jeyaraj, Kar, Baabdullah, Koohang, Raghavan, & Ahuja, 2023), the release of ChatGPT has created many controversies in different domains, including academics (Lim, Gunasekara, Pallant, Pallant, & Pechenkina, 2023; Livberber & Ayvaz, 2023; Tlili, Shehata, Adarkwah, Bozkurt, Hickey, Huang, & Agyemang, 2023). Academics are particularly concerned about the impact of ChatGPT on students' critical thinking skills, academic integrity, plagiarism, unethical use of the tool, as well as the generation of non-factual information (Lin, 2023; Livberber & Ayvaz, 2023; Mohammad, Supti, Alzubaidi, Shah, Alam, Shah, & Househ, 2023). Consequently, some educators and institutions have called for the outright banning of generative AI tools (Hung & Chen, 2023; Lim et al., 2023; Volante, DeLuca, & Klinger, 2023), while others are advocating a more responsible use (Hung & Chen, 2023; Lim et al., 2023), arguing that a wholesale ban could lead to resistance from students. In any event, many of the available plagiarism detection tools may not necessarily be effective in detecting texts written by generative AI tools like ChatGPT (Lin, 2023; Livberber & Ayvaz, 2023).

There are different application areas of ChatGPT. This includes the creative arts, healthcare, marketing,

education, and academic writing (Cascella et al., 2023; French, Levi, Maczo, Simonaityte, Triantafyllidis, & Varda, 2023; Sohail et al., 2023). For example, French et al. (2023) explored the use of ChatGPT to facilitate creative problem-solving and critical skills in undergraduate students. The authors were able to demonstrate that programming students can develop higher-order thinking skills through the intentional incorporation of generative AI tools like ChatGPT into students' projects. This is in line with the view that students should not have to use ChatGPT secretively. Rather, educators should be willing to empower students to be responsible users of new technologies. In another study, Lum (2023) reported that while ChatGPT was able to score 47% in a selection of orthopedic in-training examination questions, its performance decreased significantly as the complexity of the questions increased. Although Lum's (2023) study demonstrates the limitations of ChatGPT in the application of knowledge, the study also highlights its potential to create simplified educational materials for patients.

Given the increasing interest in generative AI tools, this paper aims to uncover new insights and trends in the publication landscape of AI in higher education by utilizing bibliometric analysis to identify the strengths, weaknesses, opportunities, and threats within the body of literature related to AI in higher education. This analysis can provide insights into the current trends, challenges, and areas for improvement in the field, which can be valuable for researchers, policymakers, and educators. The research questions that we address in the paper are:

1. Which authors, publishers, countries, and institutions are actively involved in the publication of research on the usage of generative AI tools in higher education?
2. What are the trends, patterns, and topic themes related to the usage of generative AI tools in higher education?

METHODOLOGY

Bibliometric Analysis Approach

Research synthesis is a meticulous process of collecting, evaluating, and merging extant literature on a specific topic to yield meaningful and credible findings. It involves the systematic identification, selection, critical analysis, data extraction, and synthesis of results to provide an impartial and comprehensive overview of available information (Cooper, Hedges, & Valentine, 2019). The method is typically used to analyze and integrate data, findings, and results from multiple studies, drawing reliable conclusions that extend beyond individual studies (Leary & Walker, 2018). Various methodologies, including systematic reviews, meta-analysis, meta-synthesis, and bibliometric analysis, employ a systematic approach to aggregate, analyze, and integrate results from numerous studies (Dogan, 2023) to address specific research questions and generate overall summaries or conclusions based on combined evidence (Leary & Walker, 2018).

Meta-synthesis is a qualitative paradigm that integrates and synthesizes findings from multiple studies to generate new insights beyond individual studies. In contrast, meta-analysis employs statistical methods to combine and analyze data from multiple independent studies on a specific research topic, pooling results or effect sizes to provide an overall summary estimate of the relationship between variables not explored in individual investigations (Donthu, Kumar, Mukherjee, Pandey, & Lim, 2021).

Bibliometric analysis quantitatively examines large amounts of data, focusing on assessing the bibliometric characteristics of publications and authors, such as citations, keywords, and publishing patterns, rather than summarizing the findings of individual studies. It aids researchers in understanding the intellectual landscape and emerging trends in their field (Donthu et al., 2021; Zupic & Čater, 2015). Furthermore, the quantitative approach employed in bibliometric analysis makes it easier to describe, assess, and monitor published research, introducing a systematic, transparent, and replicable review process that improves review quality. Bibliometric analysis guides researchers to key studies, which are then used to map the research field without introducing subjectivity (Zupic & Čater, 2015).

According to Donthu et al. (2021), bibliometric analysis methodologies can be categorized into performance analysis and science mapping. Performance analysis employs indicators related to publication and citation, providing insights into a field's trends. Citation analysis investigates the most frequently cited studies, authors, or journals, which are typically presented as top-N lists and are regarded as a criterion of influence. Co-citation, co-authorship, and co-word (co-occurrence) analysis are types of science mapping methods (Donthu et al., 2021; Zupic & Čater, 2015). Co-citation analysis reveals the connections among authors, journals, and references based on the frequency of co-citation in reference lists, offering insights into influential schools of thought on a subject. Co-authorship analysis reveals a field's social structure, whereas co-word analysis defines it by mapping the content of studies and highlighting connections between concepts that appear in document titles, keywords, or abstracts (Scherer, Siddiq, & Tondeur, 2019).

The study reported in this paper utilized citation and co-occurrence analyses to examine the conceptual structure of published literature to uncover the strengths, weaknesses, opportunities, and threats of the published literature on the use of Generative AI tools in higher education.

Literature Search Strategy

A search of academic literature was conducted to extract published studies reporting on generative AI in higher education. Data for the bibliometric analysis were retrieved from the Scopus database on September 13, 2023. Scopus was the database of choice because it provides access to high-quality research in different fields.

The search terms were author-defined terms with a combination of generative AI and education as subject headings. This was to ensure that pertinent sources that would help answer the research questions were retrieved. The search terms used were: "ChatGPT" OR "OpenAI" OR "generative AI") AND (education OR "Higher education" OR teaching OR learning OR literacy OR training) AND (utility OR usage OR advantage OR opportunities OR importance OR benefi* OR impact OR implication OR challeng* OR problem* OR limitation OR bias OR risk OR threats OR trend* OR issues). These search terms were directed at the title, abstract, and keyword fields in the Scopus database.

Data Extraction / Inclusion and Exclusion Criteria

To ensure that the data obtained supports the aim of the study, we assessed each article using the inclusion and exclusion criteria illustrated in Table 1. The articles were exported into an Excel spreadsheet allowing for easy filtering, sorting, and categorization. By scrutinizing the titles and abstracts, the authors excluded studies that did not align with the research objectives. This step is crucial to ensure that the final set of articles is not only relevant but also of high quality. Articles that passed the title and abstract screening process were included in the bibliometric analysis.

Table 1: Inclusion and Exclusion Criteria

Inclusion Criteria (IC)	
IC1	Articles published in English
IC2	Articles that focused on ChatGPT, generative AI, education, and higher education
IC3	Peer-reviewed articles
Exclusion Criteria (EC)	
EC1	Articles in which the abstract is not available
EC2	Conference reviews (i.e., foreword to conference proceedings), letters, editorials, surveys, notes and unspecified document types
EC3	Articles not written in the English language
EC4	Articles not relevant to the use of ChatGPT, generative AI in education or higher education

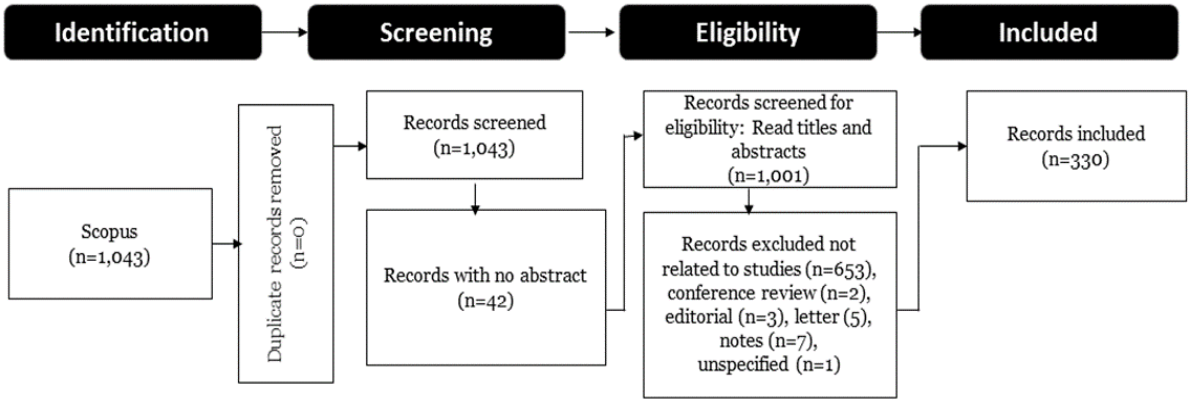

Figure 1: Flow Diagram of Database Screening using PRISMA

A total of 1,043 sources were retrieved from the Scopus database. There was no duplicate document. During the screening stage, 42 sources that had no abstracts were excluded. During the eligibility stage, the remaining 1,001 documents were screened by reading their titles and abstracts. This stage resulted in the exclusion of the following documents: sources that were not relevant to the current study (655), conference reviews (2), editorials (2), letters (5), notes (7), and unspecified document type (1). The PRISMA flowchart, illustrated in Figure 1, depicts the source screening process. Table 2 summarizes the key information about the sources included in the bibliometric analysis.

Table 2: The Primary Data on Sources Included in the Bibliometric Study

Category and Description	Results
Timespan	2017:2023
Sources (Journals, Books, etc)	228
Documents	330
Annual Growth Rate %	99,08
Document Average Age	0,709
Average citations per doc	10,64
References	11330
Document Contents	
Keywords Plus (ID)	1368
Author's Keywords (DE)	825
Authors	
Authors	1131
Authors of single-authored docs	58
Authors Collaboration	
Single-authored docs	58
Co-Authors per Doc	3,86
International co-authorships %	25,45
Document Types	
Article	189
Book	1
Book chapter	4
Conference paper	113
Review	23

RESULTS

Citation Analysis

Annual Publication Growth

A citation analysis of the 330 documents included in the bibliometric analysis was carried out using Microsoft Excel. We calculated the annual publication growth rate using the formula:

Annual publication growth rate = (number of publications in the year under consideration/number of publications in the preceding year – 1) × 100

The annual publication growth rate is illustrated in Figure 2. Only four documents were published in 2017, and 12 in 2018, representing a 200% publication growth. There was a slight dip to 11 (-8.3%) in 2019, followed by a 63.6% growth rate to 18 in 2020. The year 2021 saw another dip to 16 (-11.1%) before increasing to 20 (25% growth) in 2022. This was followed by a massive increase to 247 documents published in 2023, as of 13 September, when the documents were retrieved. This increase represents a whopping 1145% annual publication growth when compared with the number of publications in 2022. Given the high level of interest that followed the release of ChatGPT in November 2022, the significant increase in the number of publications in 2023 came as no surprise.

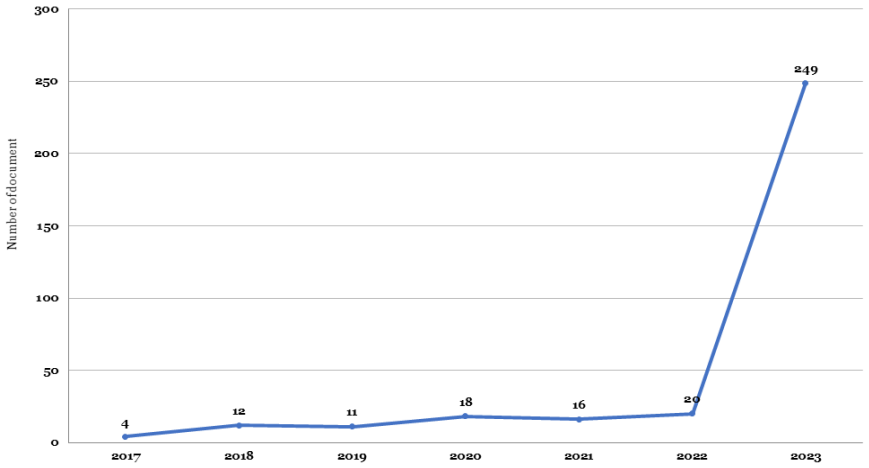

Figure2: Annual Publication Growth Rate (as of 13 September 2023)

Publisher Annual Publication Growth Rate

In addition to the annual growth rate of publications, we also analyzed the sources according to the publishers that published the most research papers related to Generative AI/ChatGPT and education. The analysis was limited to the top five publishers to ensure that the visualization was meaningful.

As illustrated in Table 3, none of the top five publishers published any document related to the use of generative AI tools in higher education in 2017 and 2018. There was only one publication in 2019, 2020, and 2021, respectively, through the ACM international conference proceeding series. This increased to three (200% annual growth rate) in 2022 and seven (133% annual growth rate) as of 13 September 2023 when the sources included in the study was retrieved.

Table 3: Annual Publication Growth Rate by the Top Five Publishers (as of 13 September 2023)

	2017	2018	2019	2020	2021	2022	2023
Annual Conference on Innovation and Technology in Computer Science Education (ITICSE)	0	0	0	2	2	2	8
ACM International Conference proceeding series	0	0	1	1	1	3	7
JMIR Medical Education	0	0	0	0	0	0	6
Journal of Chemical Education	0	0	0	0	0	0	6
Sustainability (Switzerland)	0	0	0	0	0	0	6

The Annual Conference on Innovation and Technology in Computer (ITICSE) published two documents in 2020, 2021, and 2022 respectively. This was followed by a massive 300% publication growth rate in 2023 compared to the two in the preceding year, with eight.

There were no publications through the JMIR Medical Education, Journal of Chemical Education, and Sustainability (Switzerland) between 2017 and 2022. However, each of the journals published six papers, as of 13 September 2023 when the sources included in the study were retrieved.

Publications by Document Types

Analysis of the research papers according to the document type, illustrated in Figure 3, showed that more than half of the sources (189, 57%) were articles, 113 (34%) were conference papers, 23 (7%) were reviews, while 4 (1%) were book chapters. There was only one source classified as a book.

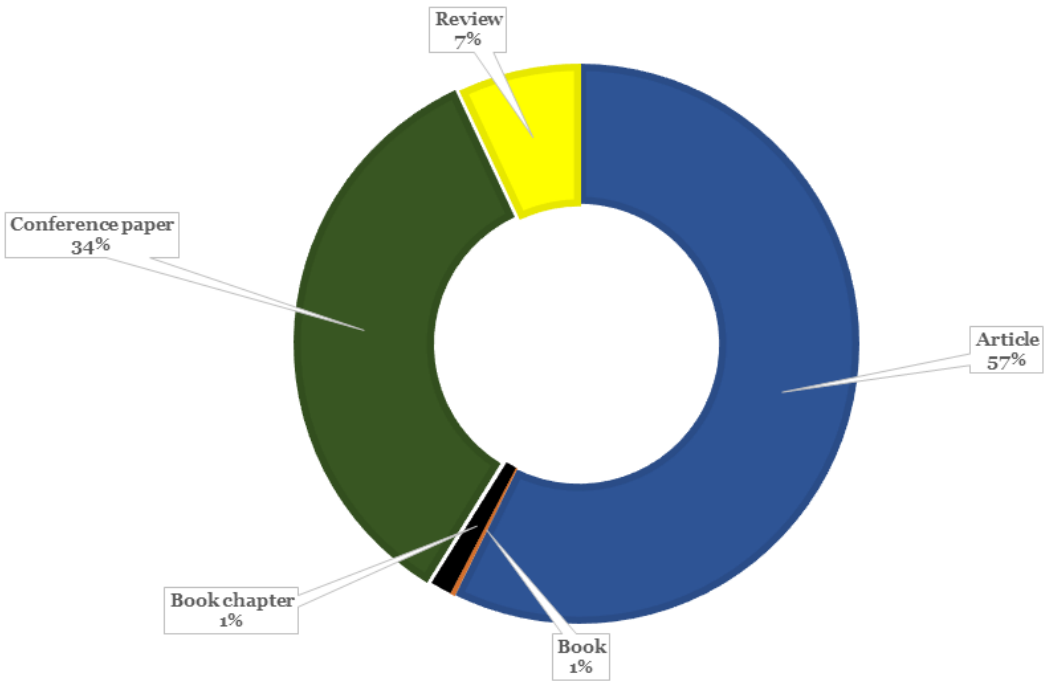

Figure: Source Distribution by Document Type (as of 13 September 2023)

Number of Publications by the Top Ten Authors

We also examined the included document based on the number of publications by authors. The 330 documents included in the bibliometric analysis were written by 1131 different authors. The top ten authors each published a total of 51 documents. The leading author published nine documents (see Figure 4). Six papers were published by the authors in the second and third positions, respectively. The authors in positions four and five published five documents each. The remaining authors (positions six to ten) published four documents each, respectively.

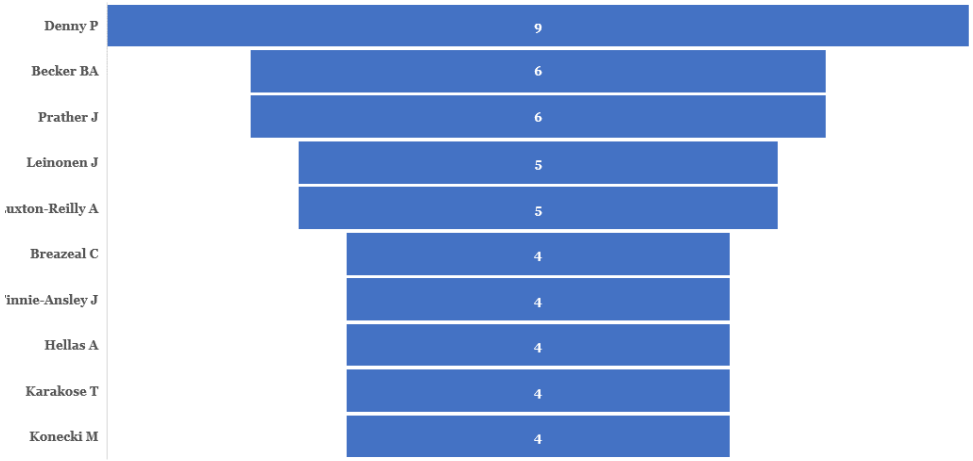

Figure 4: Number of Publications by Top Ten Authors (As of 13 September 2023)

Number of Publications by the Top Ten Countries

The documents included in the study were also analyzed according to the authors' country of affiliation using the Biblioshiny feature in Bibliometrix for R Studio. The 330 documents were spread across 61 countries. The United States of America (USA) has the highest number of documents at 271, followed by China (122), and Australia (87). Figure 5 illustrates the geographical spread of the top 10 countries.

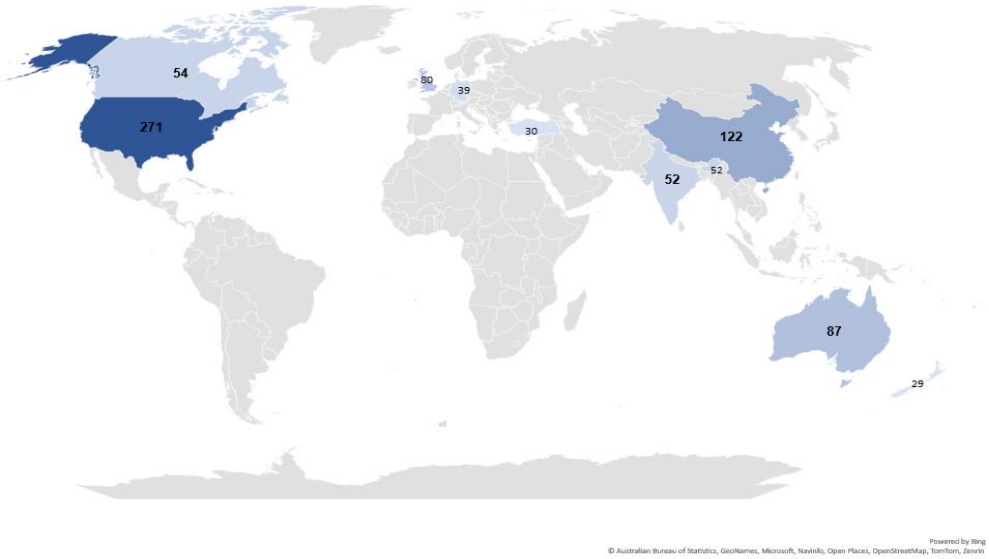

Figure 5: Geographical Distribution of Top Ten Document Countries

Number of Publications by Institutions

Using the Biblioshiny feature in Bibliometrix for R Studio, we analyzed the document included in the bibliometric analysis according to the authors' institution. As illustrated in Table 4, there are four institutions from the USA at positions one to four (17, 11, 9, and 8 documents, respectively). The institution in position five is located in Austria (eight documents). Two institutions from Canada occupied positions six and seven, with eight documents respectively.

Table 4: Top Ten Institutions

Affiliation (Country)	**Number of documents**
Massachusetts Institute of Technology (USA)	17
Yale University School of Medicine (USA)	11
University of North Texas (USA)	9
Columbia University (USA)	8
Salzburg University (Austria)	8
University of Calgary (Canada)	8
University of Toronto (Canada)	8
Australian Institute of Business (Australia)	7
Charles Sturt University (Australia)	7
Firat University (Türkiye)	7

Two institutions located in Australia each published seven documents respectively. Lastly, the institution in position ten is located in Türkiye and published seven documents.

Most-cited Publications

We utilized the Biblioshiny feature in Bibliometrix for R Studio to analyse the most cited publications on the use of generative AI in higher education. As shown in Table 5, the publication by Fujimoto, Hoof and Meger (2018) has the highest total citation count (1176). This is followed by the publication of Gilson, Safranek, Huang, Socrates, Chi, Taylor and Chartash (2023) with 128 citations, and the publication of Dwivedi et al. (2023) with a total of 122 citations.

Table 5: Top Ten Most Cited Publications (as of 13 September 2023)

Citation	Title	Total Citations
(Fujimoto et al., 2018)	"Addressing Function Approximation Error in Actor-Critic Methods"	1176
(Gilson et al., 2023)	"How Does ChatGPT Perform on the United States Medical Licensing Examination? The Implications of Large Language Models for Medical Education and Knowledge Assessment"	128
(Dwivedi et al., 2023)	"So what if ChatGPT wrote it?" Multidisciplinary Perspectives on Opportunities, Challenges and Implications of Generative Conversational AI for Research, Practice and Policy"	122
(Gu, Lillicrap, Ghahramani, Turner, & Levine, 2017)	"QProp: Sample-Efficient Policy Gradient with an Off-Policy Critic"	83
(Rudolph, Tan, & Tan, 2023)	"ChatGPT: Bullshit spewer or the end of traditional assessments in higher education?"	79
(Williams, Park, & Breazeal, 2019)	"A is for Artificial intelligence: The Impact of Artificial Intelligence Activities on Young Children's Perceptions of Robots"	71
(Pavlik, 2023)	"Collaborating with ChatGPT: Considering the Implications of Generative Artificial Intelligence for Journalism and Media Education"	69
(Salvagno, Taccone, & Gerli, 2023)	"Can Artificial Intelligence Help for Scientific Writing?"	65
(Gu, Lillicrap, Turner, Ghahramani, Schölkopf, & Levine, 2017)	"Interpolated Policy Gradient: Merging On-policy and Off-policy Gradient Estimation for Deep Reinforcement Learning"	65
(Tlili et al., 2023)	"What if the Devil is my Guardian Angel: ChatGPT as a Case Study of Using Chatbots in Education"	62

Topic Trends

We analyzed the trends of topics in published research related to the generative AI tools in higher education using the Biblioshiny feature in Bibliometrix for R Studio. As depicted in Figure 6, the emerging topics in the field of generative AI within higher education over the years are evident. In 2023, "Artificial Intelligence" dominated the conversation in literature, closely trailed by "ChatGPT" and "students". In 2022, "Learning Systems" and "Computational Linguistics" were prominent, while "Deep Learning" was the topic of prominence in 2021. Interestingly "Reinforcement Learning" was the focal theme in 2020 and 2018. Meanwhile, "Machine Learning" was the top trend topic in 2019.

Topic Dendogram

The topic dendrogram presented in Figure 7 visualizes the hierarchical structure and interrelations among the keywords through hierarchical clustering. The designated cut and vertical lines in the figure serve to simplify the exploration and comprehension of the distinct clusters. Echoing the views of Secinaro, Brescia, Calandra and Biancone (2020), Figure 7 does not strive for an impeccable alignment of cluster associations. Rather, it endeavors to estimate an approximate cluster count, laying the groundwork for deeper discussion. The dendrogram divides into two main branches. The first branch pivots around chatgpt3, linking it to domains like education computing, introductory programming, and academic integrity. The second branch centers on the themes of natural languages and students, intertwining them with a range of aspects like teaching, e-learning, policy optimization, curricula formulation, decision-making processes, writing techniques, instructional methodologies, and advanced technology models like deep learning and reinforcement learning within the educational framework.

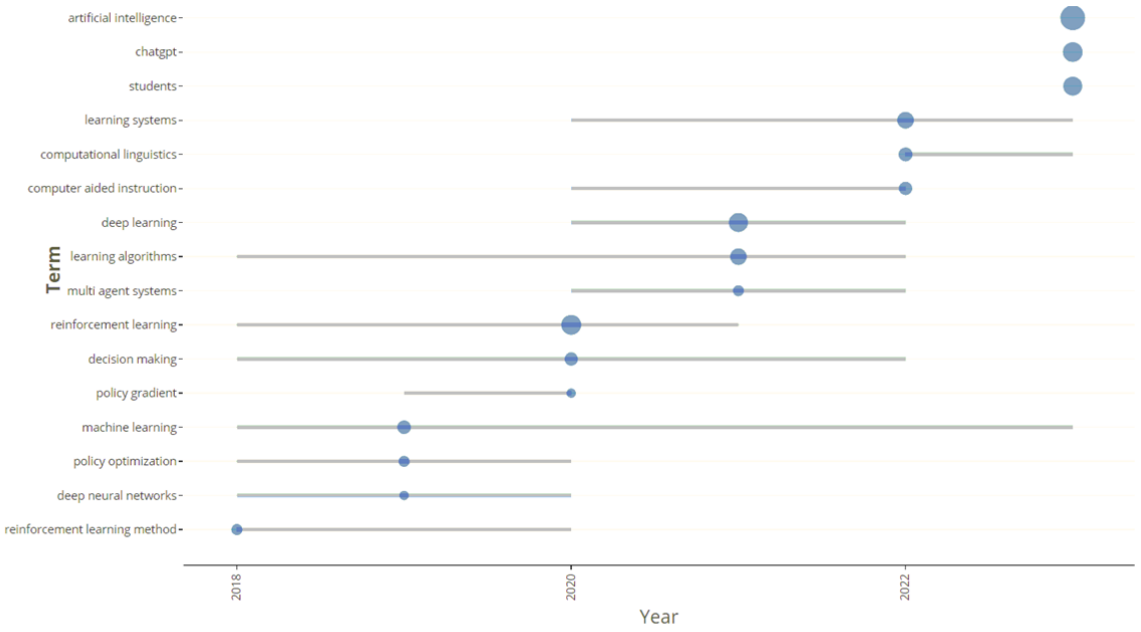

Figure 6: Visualization of Trending Topics

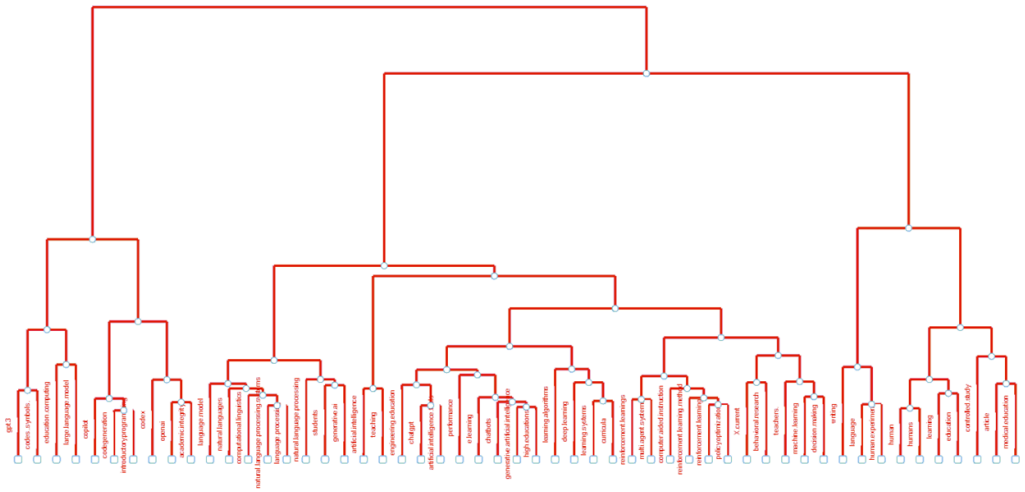

Figure 7: Topic Dendogram

Word Map

The Word Map, illustrated in Figure 8, serves as a visual representation that highlights the combination of relevant keywords integral to the study of generative AI in higher education, organized systematically. As depicted in Figure 8, all the keywords with significant contributions are illustrated on a two-dimensional factorial map. The pertinent terms specific to a domain are spread out over a two-dimensional plane. This layout helps to understand the interrelationships and patterns that emerge between words, grounded in their attributes and lexical classifications (Wu & Ye, 2021).

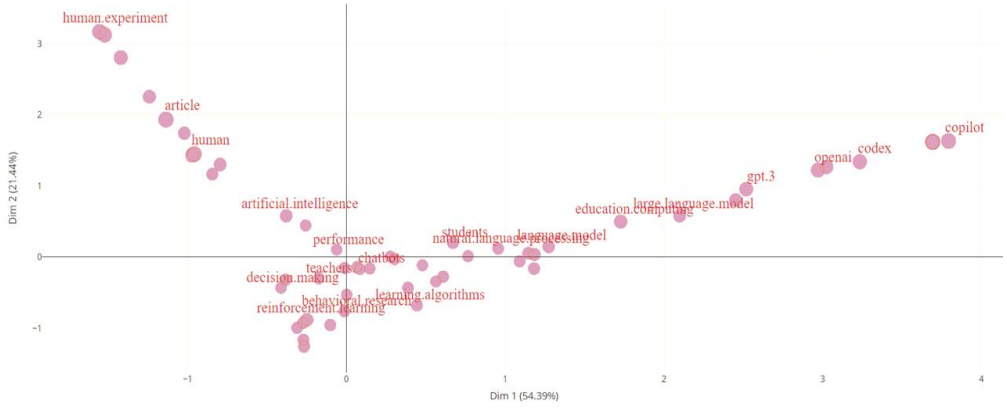

Figure 8: Word Map of Keywords

Term Co-Occurrence

To understand the conceptual structure of the body of research related to the use of generative AI in higher education, co-occurrence analysis was conducted to identify the relationship and pattern between the terms used by authors in the title and abstract of their publications. Terms that are frequently associated together indicate a strong conceptual link, depicting key topics and themes, emerging trends, and research clusters and keywords for further research in a specific field.

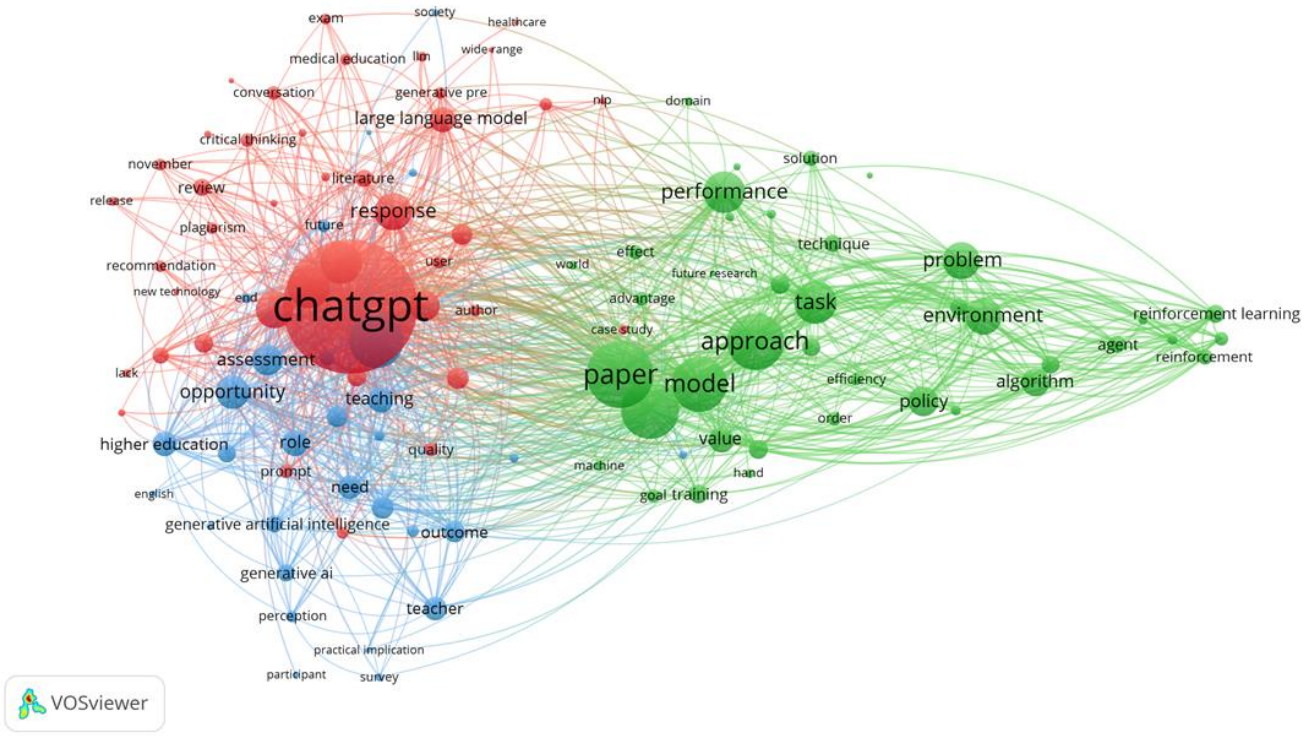

Figure 9: Network Visualization of Term Co-occurrence in Research to Generative AI in Higher Education

The binary counting method was used to extract text data from the title and abstract fields of the sources included in the bibliometric analysis using VOSViewer version 1.6.20. The minimum number of occurrences per term was set at ten. Out of the 7352 terms generated, 186 met the threshold. For each of the 186 terms, a relevance score was calculated, and 60% of the most relevant terms were chosen by default. Hence, 112 terms were finally selected. Figure 9 illustrates the network visualization of the term co-occurrence by cluster. Three clusters of terms were detected by VOSViewer. The three clusters of the most relevant terms are listed in Table 6.

The term co-occurrence network was also plotted in the overlay visualization view to understand the evolution of the most relevant terms. Figure 10 reveals that the most relevant terms in studies between the first and second half of 2021 revolved around the environment, algorithms, problems, policy, efficiency, and reinforcement learning techniques. In 2022, most researchers focused on the model, approach, task, performance, effect, advantage, and future research of generative AI. The year 2023 has witnessed an upsurge in the volume of publications on the subject, with ChatGPT being the most relevant term for the year. The most relevant terms co-occurring with ChatGPT for studies published in 2023 suggest that researchers have been exploring the role, need, quality, outcome, practical implication, perception, opportunity, assessment, response, and future of ChatGPT in higher education.

We drilled down to analyze the term "future research" to understand the direction of future research on ChatGPT and education. As illustrated in Figure 11, the term that co-exists with future research is ChatGPT. The terms "Future", "Potential Impact", "Potential application", and " Potential Use" were accentuated to triangulate the future of ChatGPT in higher education. Figures 12, 13, 14, and 15 illustrate the close co-occurrence between these terms and ChatGPT, implying that researchers are currently exploring the future, potential impact, application, and use of ChatGPT in higher education.

Table 6: The Top Most Relevant Terms per Cluster

Cluster 1 (42 Terms)	**Cluster 2 (40 Terms)**	**Cluster 3 (30 Terms)**
Academia	Advantage	Addition
Academic Integrity	Agent	AI Technology
Author	Algorithm	AI Tool
Case study	Approach	Aspect
Caution	Bias	Assessment
Chatbot	Deep Learning	Classroom
ChatGPT	Deep reinforcement learning	Educational Setting
Concern	Domain	Emergence
Content	Effect	End
Conversation	Efficiency	English
Critical Thinking	Environment	Essay
Exam	Experiment	Future
Generative pre	Framework	Generative AI
Healthcare	Future research	Generative Artificial Intelligence
Higher education Institution	Game	Higher Education
Impact	Goal	Integration
Lack	Hand	Language
Language Model	Learning	Misinformation
Large Language model	Machine	Need
Literature	Machine Learning	Opportunity
LLM	Model	Outcome
Medical Education	Number	Participant
Natural Language Processing	Open AI Gym	Perception
New Technology	Order	Practical Implication
NLP	Paper	Role
November	Performance	Society
Plagiarism	Policy	Survey
Potential Application	Problem	Teacher
Potential Benefit	Reinforcement	Teaching
Potential Impact	Reinforcement learning	Technology
Potential Use	Set	
Prompt	Solution	
Quality	State	
Recommendation	Strategy	
Release	Task	
Response	Technique	
Review	Time	
Risk	Training	
Text	Value	
Transformer	World	
User		
Wide Range		

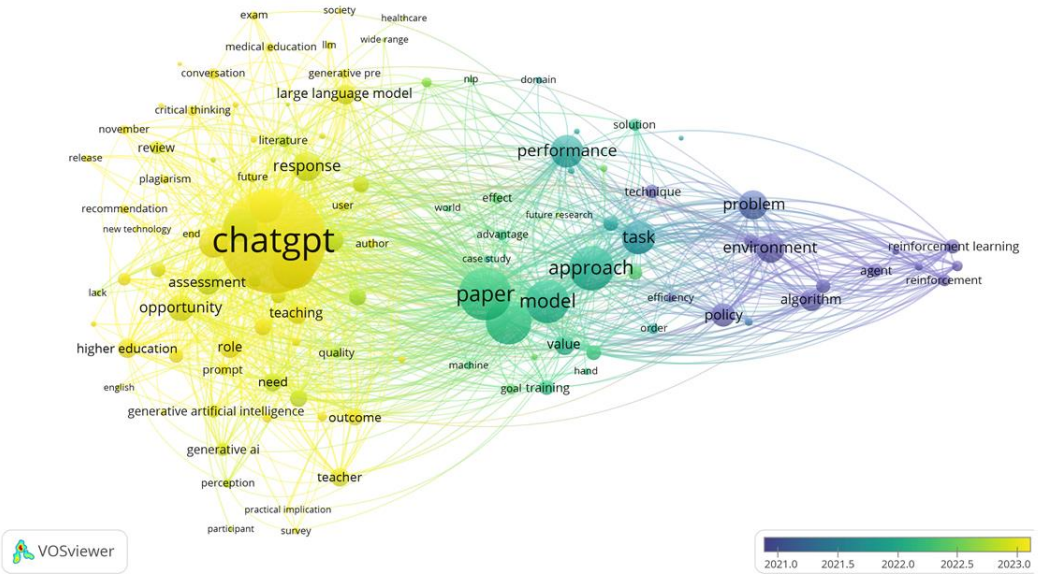

Figure 10: An overlay Visualization of Term Co-occurrence in Research to Generative AI in Higher Education

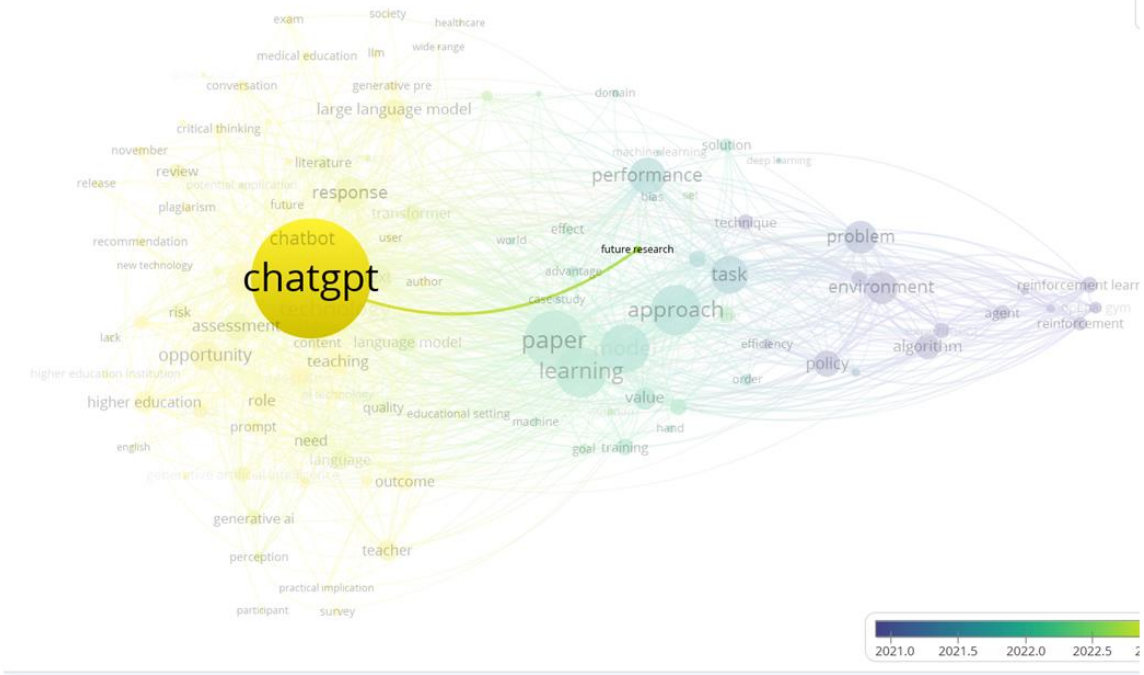

Figure 11: Future Research of Generative AI in the Higher Education.

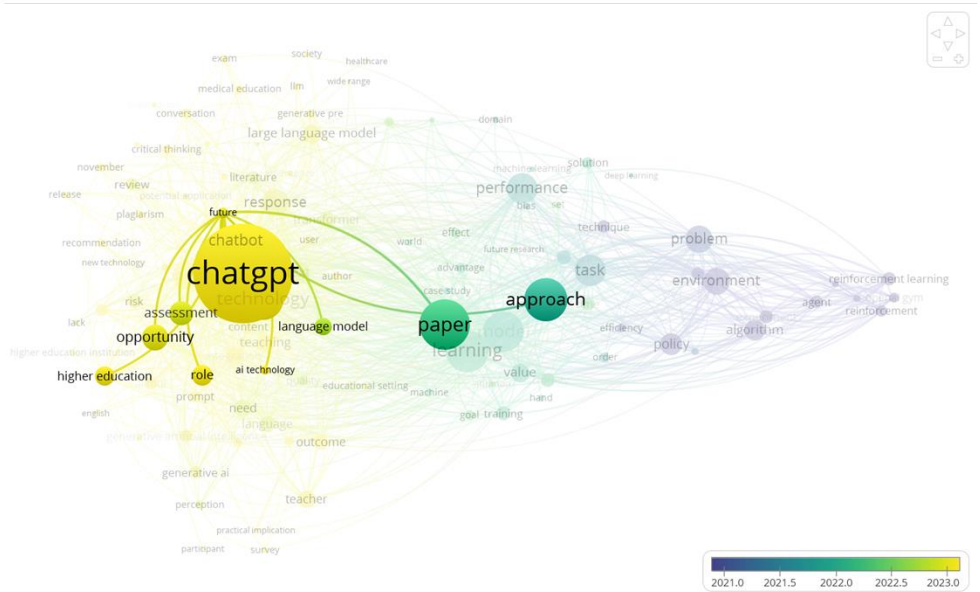

Figure 12: Future of Generative AI in Higher Education

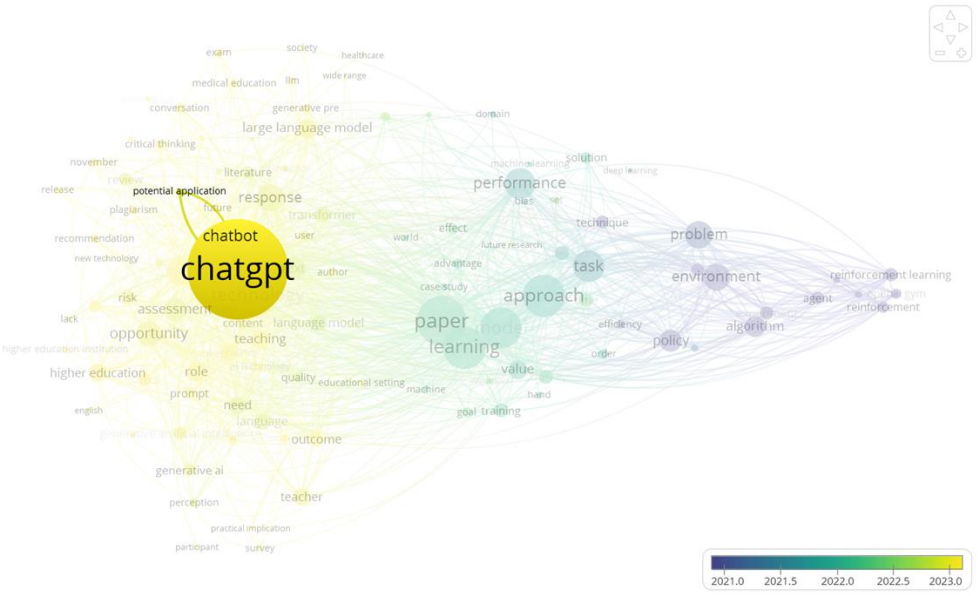

Figure: 13 Potential Application of Generative AI in Higher Education

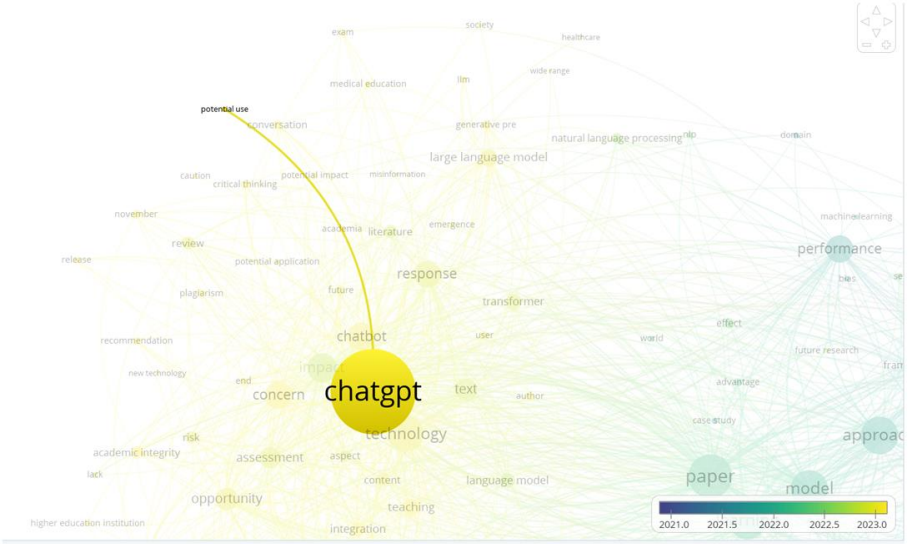

Figure 14: Potential Use of Generative AI in Higher Education

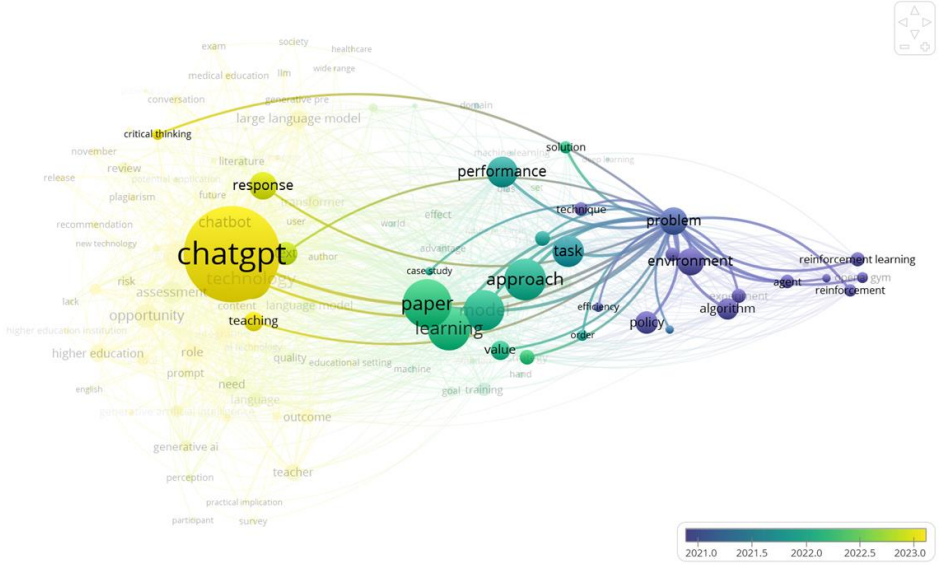

Figure 15: Problem Areas of Generative AI in Higher Education

The term "Risk" was highlighted to identify the terms that co-occur with it. Figure 16 depicts that a handful of researchers are exploring the risk associated with Generative AI in higher education. Terms closely co-occurring with "Risk" in the year 2023 include "ChatGPT," "Response," "Assessment," "Outcome," " Role," and "Higher Education," while terms like "Performance," "Task," "Approach," and "Training" were co-occurring with "Risk" in studies published before 2023.

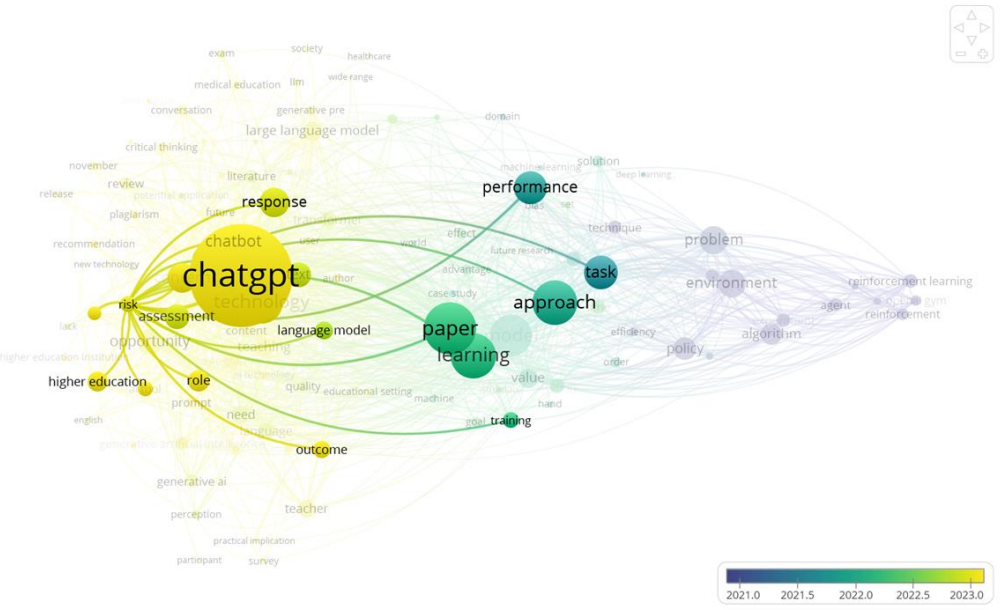

Figure 16: Risk of Generative AI in Higher Education

DISCUSSION

A SWOT analysis is one of the fundamental tools used by organizations to assess their market position. It is commonly employed to examine both internal and external organizational environments when facing uncertainty. In the past, SWOT analysis has been used in a myriad of domains, including general management, education, marketing and social media, healthcare, and agriculture (Benzaghta et al., 2021). This study aims to uncover new insights and trends in the publication landscape of AI in higher education using bibliometric analysis to identify the strengths, weaknesses, opportunities, and threats within the body of literature related to AI in higher education. To achieve this goal, we conducted citation analysis to assess the research outputs of individual researchers, institutions, publishers, and countries to understand the measure of research productivity in the domain. Research trends and emerging research areas were explored using co-occurrence analysis. This section interprets the results presented in the results section within the context of existing literature, discussing how they align with or diverge from previous studies. Thereafter, the conclusion section summarizes the study by presenting a graphical representation of the findings from this study clustered into strengths, weaknesses, opportunities, and threats of the knowledge landscape of AI in higher education.

Our analysis showed a substantial increase in the number of publications related to generative AI in higher education in 2023. This increase can be attributed to the release of ChatGPT in November 2022. Similarly, there was a substantial increase in publications at the ITICSE conference, again due to increasing attention on the topic. The majority of the publications were classified as articles, with a total of 1131 authors contributing to the publications. Most of the documents were authored by researchers from countries in the Global North. This could be attributed to the level of collaboration between authors since a particular author may be affiliated with more than one country. The most cited document was published by Fujimoto et al. (2018) with 1176 total citations, as of 13 September 2023 when the sources included in the bibliometric analysis were retrieved.

A topic dendrogram is used in bibliometric analysis to show the parent-child relationship between words in the form of a tree diagram (Wu & Ye, 2021). In the context of this study, the topic dendrogram provides a visual representation of the interconnectedness of various topics and subtopics within the field of generative AI in higher education. It highlights how different themes and domains are related and how they converge around central concepts. This analysis uncovered trends, connections, and important research directions in generative AI tools in higher education. The dendrogram (see Figure 7) is divided into two main branches, each revealing different clusters of topics and their interconnections. The first branch is centered around the key term "ChatGPT3" as a central node. This branch is linked to various domains and themes within the field of education computing, introductory programming, and academic integrity. This suggests that "ChatGPT3" is closely related to or frequently discussed in the context of these educational areas. This could also imply that researchers are exploring how chatbot technologies like GPT-3 could be applied to improve teaching,

enhance introductory programming courses, or address issues related to academic integrity. These include studies that explore ChatGPT 3.5 as a tool for learning scaffolding (Stojanov, 2023), the implications of ChatGPT 3.5 and 4 and its impact on librarianship, academia, scholarly research, the workplace (Holland, 2023), and the potential benefits, limitations and academic integrity of ChatGPT 3.5 in higher education (Marron, 2023).

Further, the potential of LLMs in computing education is being explored by researchers from diverse perspectives. This includes the use of the codex model to solve Parsons problems over various prompt variations (Reeves, Sarsa, Prather, Denny, Becker, Hellas, Kimmel, Powell, & Leinonen, 2023), the effect of AI Code Generators on supporting novice learners in introductory programming (Kazemitabaar, Chow, Ma, Ericson, Weintrop, & Grossman, 2023), the implications of OpenAI codex on introductory programming (Finnie-Ansley, Denny, Becker, Luxton-Reilly, & Prather, 2022), the potential of LLMs in generating explanations to scaffold students' ability to understand and explain codes (Leinonen, Denny, MacNeil, Sarsa, Bernstein, Kim, Tran, & Hellas, 2023) and the educational opportunities and challenges of AI code generation in computing education (Becker, Denny, Finnie-Ansley, Luxton-Reilly, Prather, & Santos, 2023).

The second branch of the topic dendrogram is centered on the themes of "Natural languages" and "Students", highlighting interconnections between different subtopics. These include teaching methodologies, e-learning, policy optimization, curricula formulation, writing techniques, and advanced technology models like deep learning and reinforcement learning. This complex network of interconnected subtopics suggests an exploration of how natural language processing and AI technologies can be leveraged to enhance the student learning experience in higher education. Notable studies in this cluster include the use of GPT-3 to solve math word problems (Zong & Krishnamachari, 2023), the potential of ChatGPT as a powerful medical writing tool to generate summaries, proofread, and provide valuable medical insight (Ho, Koussayer, & Sujka, 2023), the diverse application areas of ChatGPT in different domains, including healthcare, marketing and finance, research and academic writing, environmental science, and natural language processing (Sohail et al., 2023).

The analysis of term co-occurrence was leveraged to uncover patterns, relationships, and key concepts within a body of literature in the use of Generative AI in higher education, contributing to a deeper understanding of the conceptual and intellectual landscape in the field. The most relevant terms were presented as clusters within a co-occurrence network. The unit of analysis was the topics and abstracts of studies included in the bibliometric analysis. Each cluster consists of multiple terms that tend to appear together in the literature, suggesting some degree of interconnectedness and common themes within these clusters. In other words, these terms tend to appear together in research papers, suggesting that they are conceptually related or are frequently discussed concerning each other. For example, terms like "Academic Integrity," "Plagiarism," "Critical Thinking," and "Author" could be interconnected in the context of educational research, as they often relate to issues of ethics and authorship. "Chatbot," "ChatGPT," "Natural Language Processing," and "Language Model" may be interconnected as they likely pertain to the use of AI and chatbots in the context of education or healthcare. "Medical Education" and "Healthcare" may also be strongly connected. Notable studies in this cluster explored potential ethical issues that could arise with the emergence of LLMs like GPT-3 (Lund, Wang, Mannuru, Nie, Shimray, & Wang, 2023), the challenges and risks of algorithmic decision-making and algorithmic fairness, such as accuracy and explainability involved when using generative AI for decision making (Fischer, 2023), the educational transformation, response quality, usefulness, personality and emotion, and ethical implication of ChatGPT in education (Tlili et al., 2023), the limitations, disruptions to practices, threats to privacy and security, and consequences of biases, misuse, and misinformation of generative AI for research, practice and policy (Dwivedi et al., 2023), and the potential impact of Chat GPT on academia and scholarly research and publishing.

Cluster 2 appears to be focused on machine learning, especially deep reinforcement learning and reinforcement learning, with a strong emphasis on algorithms, strategies, and future research directions. Many terms in this cluster revolve around machine learning, including "Machine Learning," "Deep Learning," "Deep Reinforcement Learning," "Reinforcement Learning," and related concepts. This indicates a strong emphasis on these areas within the analyzed publications. Terms like "Reinforcement," "Policy," "Game," and "Value" suggest a concentration on reinforcement learning, particularly in the context of game-based applications (Cao, 2022; French et al., 2023; Ho & Lee, 2023). Terms like "Algorithm," "Approach," "Technique," and "Strategy" imply that research in this cluster is focused on developing and assessing various algorithms and strategies for machine learning. The literature in this category explored the methods and strategies to confront the challenges regarding academic integrity associated with ChatGPT using machine learning algorithms like Support Vector Machine (SVM) (Cingillioglu, 2023), the performance of several reinforcement learning algorithms such as Deep-Q-Network, Neural Fitted Q-Iteration and Vanilla Policy Gradient for discrete learning environments, including a 2D maze and two OpenAI Gym environments, namely a custom-built Foraging/Tagging environment and the CartPole environment (Duarte, Lau, Pereira,

& Reis, 2020). The presence of terms like "Future Research" and "Experiment" suggests a forward-looking approach, emphasizing the need for future research and experimental work in this domain. Many of the recommendations for future research were calls to explore potential benefits, challenges, and further use cases of ChatGPT in Higher Education.

According to Ray (2023), ChatGPT can be applied in diverse domains. Hence, we asked ChatGPTv4 about its roles in shaping future research within the sphere of higher education. Curriculum development, student support and tutoring, research assistance, enhancing accessibility, data-driven insights, academic writing and publication, learning analytics, facilitating academic collaboration, automating administrative tasks, professional development, ethical and critical thinking, innovation in teaching, thesis advising, and grant writing were the 14 key areas that ChatGPTv4 identified, in response to our prompt. To buttress these key areas, Rasul, Nair, Kalendra, Robin, de Oliveira Santini, Ladeira, Sun, Day, Rather, & Heathcote (2023) highlighted five future research directions of ChatGPT in higher education in their work on generative AI, which include facilitating adaptive learning, personalized feedback, aiding research, automated administrative services, and innovative assessment creation. Firat (2023) on the other hand, opined that future research should focus on the potential applications and impacts of AI in education, as well as the development of effective frameworks for integrating AI into curricula, assessments, and pedagogy.

The interconnectedness of the terms within Cluster 3 suggests that the studies may be examining the application and impact of Generative AI in higher education, with a focus on teaching and learning, assessment, outcomes, practical implications, societal effects, and the technology itself. Likely, these terms co-occur frequently in research papers, indicating their relevance and interrelatedness within this specific academic context. As shown in Table 6, we can identify some interconnectedness and thematic associations among the terms. These include "Generative AI" serving as central nodes or themes within this cluster, suggesting that this cluster is primarily concerned with AI technologies that can generate content or solutions (Cingillioglu, 2023; Exintaris, Karunaratne, & Yuriev, 2023; Fergus, Botha, & Ostovar, 2023). The term "Higher Education" points to the specific context of this study, indicating that the focus is on how Generative AI impacts or is applied in higher education (Alshahrani, 2023), while terms like "Educational Setting," "Classroom," "Teacher," and "Teaching" are closely related and suggest that the studies may be exploring how Generative AI is used in educational settings by teachers in their teaching practices (Livberber & Ayvaz, 2023; Su, Lin, & Lai, 2023). "Assessment," "Outcome," and "Practical Implication" indicate that the studies were exploring how Generative AI technology impacts assessments (Ali, Barhom, Tamimi, & Duggal, 2023; Mihalache, Popovic, & Muni, 2023), the outcomes it produces (French et al., 2023; Wu & Yu, 2023), and its practical implications in higher education (Mizumoto & Eguchi, 2023; Rodríguez, Montoya, Fernández, & Lara, 2023). The terms "Language," "English," and "Essay" suggest a focus on the role of language and written content, such as essays, possibly in the context of AI-generated writing or language-related applications (Alexander, Savvidou, & Alexander, 2023; Żammit, 2023). The terms "Misinformation," "Society," and "Survey" could indicate an exploration of the societal impact of Generative AI, especially concerning the spread of misinformation (Dwivedi et al., 2023; Livberber & Ayvaz, 2023), which is an important topic in the use of AI-generated content.

The terms in each cluster have evident interconnectedness as they share common themes and topics. These clusters provide a clear overview of the different aspects of Generative AI in higher education that have been explored in the analyzed documents, ranging from academic integrity and deep learning to teaching strategies helping to identify patterns and key themes in academic literature and research, offering valuable insights for researchers and policymakers.

CONCLUSION

This study conducted a comprehensive bibliometric analysis to uncover new insights and trends in the publication landscape of AI in higher education and to identify the strengths, weaknesses, opportunities, and threats within the body of literature in the domain. The study analyzed research outputs, trends, and emerging areas using citation and co-occurrence analysis. The surge in publications from four in 2017 to 247 in 2023, a remarkable 1145% annual growth, compared with only 20 in 2022, highlights the impact of ChatGPT's release in November 2022. Notable trends include increased publications in conferences like ITICSE, signalling a heightened focus on the topic.

The topic dendrogram visually presents the interconnectedness of various topics and subtopics within generative AI in higher education. The first branch, centered around "ChatGPT3," indicates a connection with education computing, introductory programming, and academic integrity. Noteworthy studies explored the application of ChatGPT, from learning scaffolding to its impact on librarianship, academia, and academic integrity. The second branch of the dendrogram focused on "Natural Languages" and "Students," interconnecting with themes like "Teaching Methodologies," "E-learning," and "Deep Learning". Studies in

this cluster delved into applications of natural language processing in peer feedback, academic integrity, math problem-solving, and the diverse application of ChatGPT in healthcare, marketing, and education.
Term co-occurrence analysis further uncovered patterns and relationships, presenting relevant terms as clusters. These clusters provided insights into the interconnectedness and common themes within each cluster. The clusters explored the application and impact of Generative AI in higher education, emphasizing teaching, assessment, outcomes, practical implications, and societal effects, and machine learning, especially deep reinforcement learning, strongly emphasizing algorithms and strategies. Figure 17 presents a visual representation of the SWOTs of the knowledge landscape in AI in higher education.

Figure17: SWOTs of the knowledge landscape in AI in higher education

The bibliometric analysis revealed clear patterns and themes within generative AI in higher education, providing valuable insights for researchers and policymakers. The interconnectedness of terms in each cluster showcased the diverse aspects explored in the literature, ranging from teaching strategies and societal impacts to machine learning algorithms and future research directions. This study contributes to a comprehensive understanding of the use of Generative AI in higher education, guiding future research endeavors.

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