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Unveiling AI in Education: A Global Bibliometric Review of Research Trends, Key Theories, and Innovations

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ABSTRACT

The rapid advancement of Artificial Intelligence (AI) has profoundly transformed education, revolutionizing teaching methodologies, student engagement, and institutional decision-making. However, despite the increasing integration of AI-driven technologies such as intelligent tutoring systems, adaptive learning platforms, and generative AI tools like ChatGPT, there remains a pressing need for a systematic evaluation of research developments in this field. This study conducts a comprehensive bibliometric analysis to map global research trends, theoretical foundations, and key innovations in AI-powered education.Utilizing data from Scopus and Web of Science (WoS), this study analyzes 23,132 valid research papers using ScientoPy, a specialized bibliometric tool. The findings reveal a substantial surge in AI-related educational research, particularly post-2020, transitioning from theoretical discussions to practical applications in personalized learning, machine learning-driven assessments, and ethical AI governance. The United States, China, and the United Kingdom emerge as the leading contributors, while prolific publication sources include ACM International Conference Proceeding Series, Sustainability, and Education and Information Technologies. Citation analysis identifies influential studies that have shaped AI-driven educational policies, with prominent works addressing AI-assisted evaluations, the ethical challenges of AI in academic settings, and the role of generative AI in shaping modern pedagogy. This research also highlights dominant theoretical frameworks, including Self-Determination Theory and Activity Theory, offering insights into the cognitive and behavioral aspects of AI-enhanced learning environments. Moreover, emerging trends indicate growing research interest in AI applications in K-12 education, interdisciplinary collaborations, and the ethical implications of AI-generated content in academia. By presenting a data-driven bibliometric perspective, this study serves as a critical resource for educators, policymakers, and researchers, fostering informed decision-making and promoting the responsible integration of AI in educational landscapes.

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1. Introduction

Artificial Intelligence (AI) is significantly transforming the educational landscape by reshaping pedagogical methodologies and enhancing student learning experiences. The integration of AI-driven technologies such as intelligent tutoring systems (ITS), adaptive learning platforms, and generative AI tools like ChatGPT is becoming increasingly prevalent in educational settings [1]. Research indicates that these technologies facilitate personalized learning, enhance student engagement, improve instructional efficiency, and support data-driven decision-making within academic institutions [7,8]. The adoption of AI in education is crucial as it directly impacts student satisfaction, which in turn influences academic performance, retention rates, and overall institutional success [3,4,6].

Understanding the factors that contribute to student satisfaction in AI-driven educational environments is essential for educators, policymakers, and researchers aiming to optimize these learning contexts. A comprehensive examination of AI education trends can yield valuable insights into its effectiveness, adoption challenges, and emerging innovations [3,22]. Despite the growing body of research on AI in education, there remains a pressing need for systematic approaches to assess the intellectual structure and development of this field. Bibliometric analysis emerges as a powerful tool for this purpose, providing a data-driven perspective on the evolution of AI in educational research [2,18]. By systematically analyzing academic publications, bibliometric methods can identify influential studies, prolific authors, key theoretical frameworks, and emerging research themes, thereby guiding future investigations and policy decisions.

This study also undertakes a global bibliometric analysis of AI in education, utilizing data from Scopus and Web of Science (WoS) to map research trends, identify foundational theories, and highlight influential contributions within the field. Employing ScientoPy, a specialized bibliometric tool, this research analyzes 23,132 publications, offering a comprehensive overview of the AI education landscape. The findings aim to serve as a foundational resource for scholars, educators, and policymakers, contributing to the academic discourse on AI in education and facilitating evidence-based decision-making for the responsible and effective implementation of AI technologies in learning environments.

Despite the increasing volume of research on AI in education, several critical gaps remain unaddressed. Firstly, while many studies explore AI's role in higher education, there is a lack of comprehensive research on its impact in primary and secondary education settings. Secondly, while ethical concerns regarding AI use in academia are frequently discussed, empirical studies assessing the real-world implications of AI-driven assessments and automated grading remain scarce. Furthermore, interdisciplinary research integrating educational psychology, AI ethics, and pedagogy is still underdeveloped. Addressing these gaps will be crucial in fostering a more holistic understanding of AI's role in shaping future learning environments. The research questions guiding this study presented below

i. What What trends have emerged in the quantity and categories of publications related to AI education research?
ii. What are the most prolific source titles and common themes identified in this field?
iii. What are the most underpinning theories used in this research?
iv. Which countries are leading the research field?
v. Which articles have received the most citations, indicating their influence on the discourse surrounding AI education?

Through answering these questions, this study aims to enhance the understanding of AI education's and highlight opportunities for future interdisciplinary collaboration.

2. Methodology

To address the first research question examining trends in the quantity and categories of publications related to AI in education a bibliometric analysis was conducted using data from Scopus and Web of Science (WoS), two of the most comprehensive and widely recognized academic databases. These databases were selected due to their extensive multidisciplinary coverage and their ability to provide robust bibliometric insights into research trends, citation impact, and academic contributions. The dataset for this study was compiled by retrieving AI-related educational research publications from Scopus and WoS using a systematic search strategy to ensure comprehensive literature collection. The search terms included "Artificial Intelligence in Education," "AI-powered learning," "Machine learning in education," "Intelligent tutoring systems," "Adaptive learning technologies," and "ChatGPT in education." The search was conducted using title, abstract, and keyword filters to identify publications explicitly focused on AI applications in education, with Boolean operators (AND, OR) used to refine the queries. The study covered all relevant research published up to 2024, with a strong emphasis on post-2020 publications due to the notable surge in AI-related studies in education. The bibliometric data extracted from Scopus and WoS were processed using ScientoPy, a specialized Python-based bibliometric analysis tool. First, duplicate records were identified and removed to ensure dataset reliability, resulting in a refined dataset of 23,132 valid publications. Then, ScientoPy was used to analyze publication trends, revealing a significant increase in AI-related educational research, particularly after 2020. Publications were categorized by document type, such as research articles, conference papers, and book chapters, and by thematic focus areas, including AI-driven pedagogy, ethical considerations, and institutional implementation. The citation analysis function of ScientoPy identified highly cited studies, helping determine the most influential works shaping AI education research. To present the findings effectively, bibliometric maps and trend graphs were generated using ScientoPy, providing a clear visual representation of the evolution of AI in education research. By following these steps, this study offers a detailed overview of AI-powered classroom research trends and highlights areas for future exploration in the field.

2.1 Database and Software

In this study, the Scopus and WoS (Web of Science) databases were selected as the primary academic sources for analyzing publications related to Artificial Intelligence (AI). These databases are widely recognized by scholars as essential tools for accessing relevant scientific publications due to their multidisciplinary nature and extensive coverage. Both Scopus and WoS provide search analysis tools that enable researchers to generate representative statistics, making them particularly useful for bibliometric analysis. To facilitate the analysis, this study utilizes ScientoPy, a specialized software implemented in Python, designed for processing publication data from Scopus and WoS [2]. ScientoPy is an essential tool for evaluating various publication parameters, including research topics, authorship, institutional contributions, country of origin, document types, and keyword trends. Additionally, it enables the construction and visualization of bibliometric networks such as co-citations, bibliographic couplings, and co-authorship relationships, providing valuable insights into the evolving landscape of AI in Education.

2.2 Pre-processing of Retrieved Dataset

The dataset acquired underwent a preliminary pre-processing phase, which involved eliminating duplicate entries and integrating associated data relevant to the role of AI in education. Data

processing was carried out using ScientoPy software. Table 1 presents the preliminary results obtained from pooled data following data integration and duplicate removal. The dataset initially contained a total of 28,643 research papers related to AI in education, sourced from the Web of Science (WoS) and Scopus databases. However, 3534 documents, representing a small percentage of the total, were excluded based on their classification. After this removal, 23,132 papers remained for analysis. Among the total, 8,340 papers (36.10%) were obtained from WoS, while 14,792 papers (63.90%) were sourced from Scopus. After applying filters to select specific document types—such as research articles, conference papers, book chapters, and reviews the final number of valid publications was determined. The acquisition of data exceeding 100 entries facilitates a thorough bibliometric analysis.

Table 1
Data integration and duplicate elimination

Data Pre-processing Output	Information	Number	Percentage (%)
Initial data set processing	Total Papers from WoS and Scopus	28643	-
	Documents omitted by type	3534	12.30
	WoS data Sets	8361	33.30
	Scopus data Sets	16748	66.70
	Total publications after selecting document types (Research articles, conference papers, book chapters, review papers, and proceedings)	25109	87.70
Duplicates removing	Duplicated publications from WoS	21	
	Duplicated papers from Scopus	1956	
Reliable and valid data set	Publication WoS	8340	36.10
	Publication Scopus	14792	63.90
	Total of Valid data set	23132	

Source: Author, using ScientoPy 2.1.3

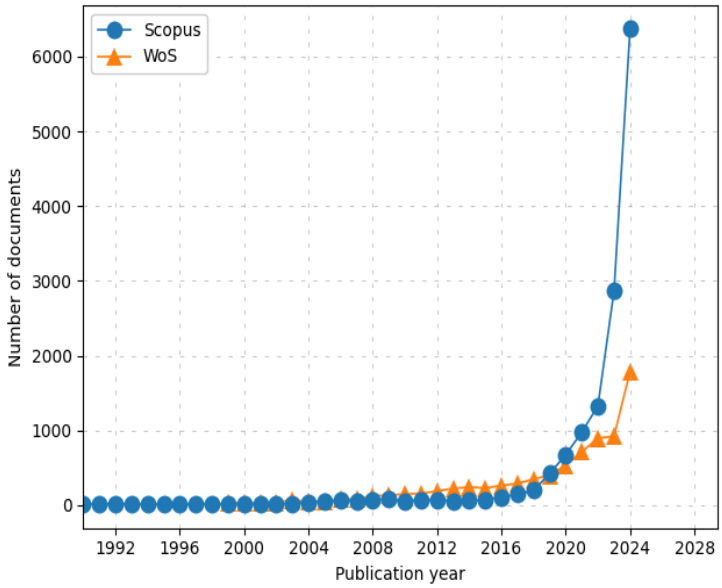
3. Results

The results of the present study are available to answer each research question outlined in the methodology section. The graphical visualization of ScientoPy is deployed to show the findings.

3.1 Publication Trends

Figure 1 illustrates the number of publications on AI in Education research has experienced remarkable growth over time, as evidenced by data from Scopus and the Web of Science (WoS). In the early years, particularly from 1990 to 2010, the number of publications was relatively low, with cumulative totals from Scopus around 200, indicating that AI in education was not a prominent research area. However, a significant shift began around 2011, coinciding with advancements in AI technologies and their applications in educational contexts, leading to a surge in publications. By 2020, Scopus reported over 2,800 documents, while WoS contributed nearly 1,000, marking a critical phase of increased interest from researchers and educators. The trend escalated exponentially from 2021 onward, with Scopus recording over 6,000 papers in 2023, reflecting the rapid evolution of AI technologies, particularly during the COVID-19 pandemic, which highlighted the importance of online learning. This bibliometric analysis indicates that AI in education has transformed from a niche area into a significant field of study, with the continuous rise in publication numbers underscoring the growing recognition of AI's potential to improve educational methodologies and outcomes. As technology advances, this trend is expected to persist, leading to further innovative research and

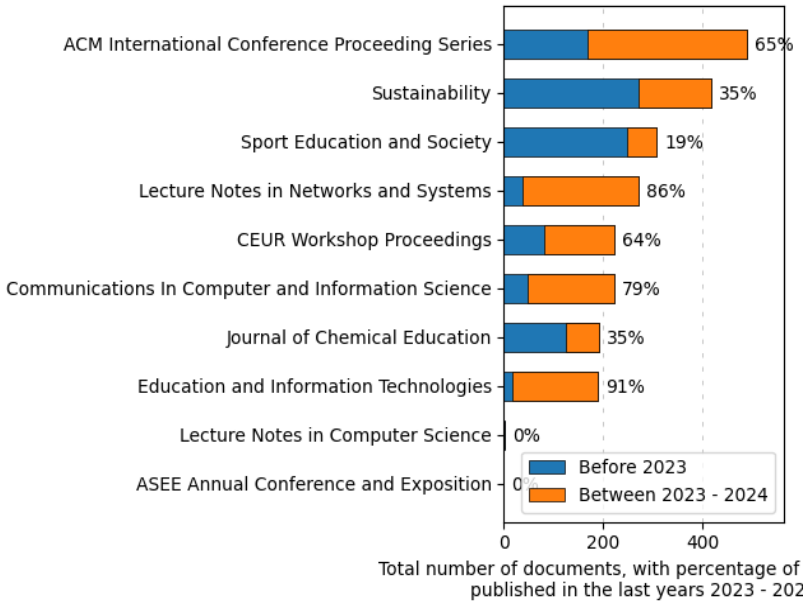
applications in the coming years, emphasizing the importance of ongoing investigation to fully harness AI's capabilities in education.



Source: Author, using ScientoPy 2.1.3
Fig. 1. The evolution of publication growth

3.2 Prolific Source Titles

This study includes the selection of source titles that have been identified as highly prolific in terms of publishing research on the topic of AI in education, several journals have emerged as key publishers, significantly contributing to the research landscape. Figure 2 show that the ACM International Conference Proceeding Series leads the way with a total of 488 publications, accounting for 65% of its output from 2023 to 2024, making it a prime venue for research that intersects with educational applications of AI. Following closely is the journal Sustainability, which has published 417 papers, with 35% of its recent output highlighting the importance of sustainable practices in education. Another significant contributor is Sport Education and Society, with 308 publications, where 19% are from the most recent years, showcasing how AI can be applied in diverse educational contexts. The Lecture Notes in Networks and Systems has 271 papers, with a remarkable 86% of its recent output reflecting the growing interest in networked systems and AI technologies in education. Similarly, Communications in Computer and Information Science has produced 221 papers, with 79% of its recent research emphasizing the application of information science to educational practices. Other noteworthy journals include the Journal of Chemical Education and Education and Information Technologies, with 192 and 188 publications, respectively; the former shows a 35% contribution from recent years, while the latter boasts a significant 91% share of its publications in the latest period, indicating a robust focus on the intersection of education and technology. Lastly, ASEE Annual Conference and Exposition, and CEUR Workshop Proceedings contribute 171 and 222 publications, respectively, with CEUR showing a recent spike in interest, underscoring the vital role of workshops and conference proceedings in disseminating cutting-edge research in AI in education. These journals not only reflect the vibrant academic discourse surrounding AI in education but also highlight the diverse applications and interdisciplinary approaches within this rapidly evolving field.



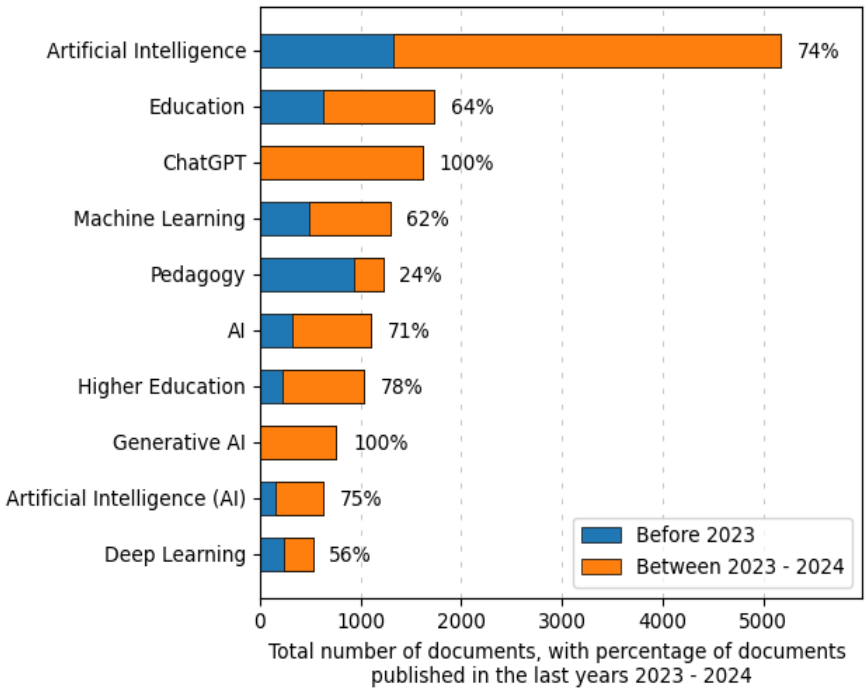
Source: Author, using ScientoPy 2.1.3

Fig. 2. The prolific source titles

3.3 Research Themes or Topics Emerging

This study employs ScientoPy to analyse the authors' keywords and examine the prevailing research trends and intriguing topics AI in education. Based on Figure 3, the most common research topics in this field is Artificial Intelligence, which accounts for an impressive 5,179 publications, with 74% of these being published in the last two years. This indicates a strong focus on the foundational technologies and their applications in educational contexts, underscoring the significance of AI as a transformative element in teaching and learning processes. Following closely is the topic of Education, which has garnered 1,729 publications, with 64% of its output emerging recently. This broad category encompasses various aspects of educational theory and practice, highlighting the integration of AI within traditional educational frameworks. ChatGPT has also gained traction, with 1,621 publications and an impressive 100% of its papers published in the last two years, reflecting the rapid rise of conversational AI tools in educational settings. Machine Learning is another critical area, with 1,291 publications and 62% of its output from recent years, emphasizing its role in personalized learning and data-driven educational strategies. The topic of Pedagogy has 1,222 publications, with 71% of these emerging in the last two years, showcasing the intersection of teaching methods and AI technologies.

The topic of AI itself, distinct from the broader category of Artificial Intelligence, has 1,108 publications, with a significant 206.5% growth in recent years. Higher Education is also notable, with 1,036 publications, indicating a substantial interest in how AI can reshape higher learning institutions, with 78% of its recent output. Additionally, Generative AI has emerged as a prominent topic, reflecting the growing interest in AI systems that create content, with 757 publications and 100% of its output from the last two years. The term Artificial Intelligence (AI) appears separately in the data, with 631 publications, showcasing the nuanced discussions surrounding AI's various facets in education. Finally, the topic of Deep Learning has 525 publications, with 56% of these being published recently, illustrating its application in more complex educational AI systems. These common research topics reflect a vibrant academic interest in how AI technologies can enhance educational practices, improve learning outcomes, and transform pedagogical approaches, indicating the ongoing evolution of this dynamic field.



Source: Author, using ScientoPy 2.1.3

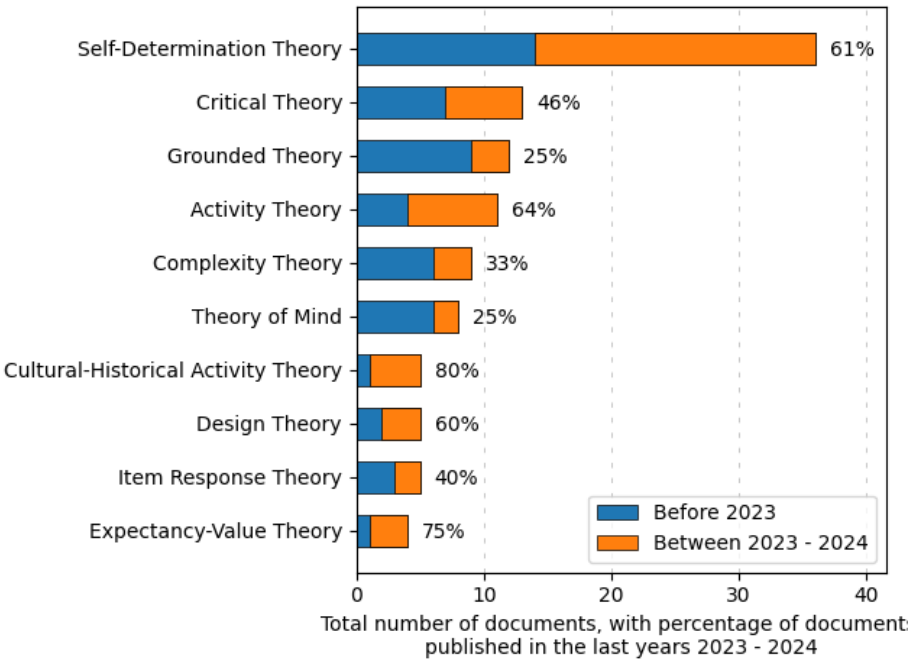
Fig. 3. The bar-trend graph of research themes and topics

3.4 Theories

In the analysis of AI in education, various theoretical frameworks have emerged as significant areas of focus, reflecting the diverse approaches researchers are taking to understand and implement AI technologies in educational contexts. Based on Figure 4, the most prominent theory is the Self-Determination Theory, which accounts for 36 total publications, with an impressive 61% of these being published in the last two years. This theory emphasizes the importance of intrinsic motivation and autonomy in learning, suggesting that AI applications should enhance learners' sense of agency and engagement. Following this, Critical Theory has also gained traction, with 13 publications and 46% of its recent output, highlighting the importance of examining power dynamics and social justice issues in educational technologies. Grounded Theory presents 12 publications, capturing 25% of its recent discussions, which often focus on building theories based on empirical data gathered from educational settings. The Activity Theory has 11 publications, with 64% being recent, reflecting a focus on the interactions between learners, tools, and their environments, which is crucial for implementing AI effectively. The Complexity Theory has 9 publications, with 33% of these being recent, emphasizing the intricate dynamics within educational systems when integrating AI.

Meanwhile, the Theory of Mind has a total of 8 published documents, with 25% of them (2 documents) published between 2023-2024, indicating some recent interest. Compared to other theories, its publication rate is lower, especially when contrasted with Self-Determination Theory with 36 documents. Despite this, its continued presence in recent years highlights its relevance in ongoing research discussions. Additionally, Cultural-Historical Activity Theory and Design Theory both have 5 publications each, with 80% and 60% of their outputs being recent, respectively. This suggests a growing interest in how cultural and historical contexts influence learning activities and the design of educational technologies. Lastly, the Item Response Theory and Expectancy-Value Theory have 5 and 4 publications, respectively, with the latter showing a notable 75% of its output in recent years, indicating its relevance in understanding students' motivations and expectations in AI-enhanced

learning environments. These theoretical frameworks not only provide a foundation for understanding the implications of AI in education but also guide researchers in designing and evaluating AI applications that effectively meet learners' needs and enhance educational outcomes.



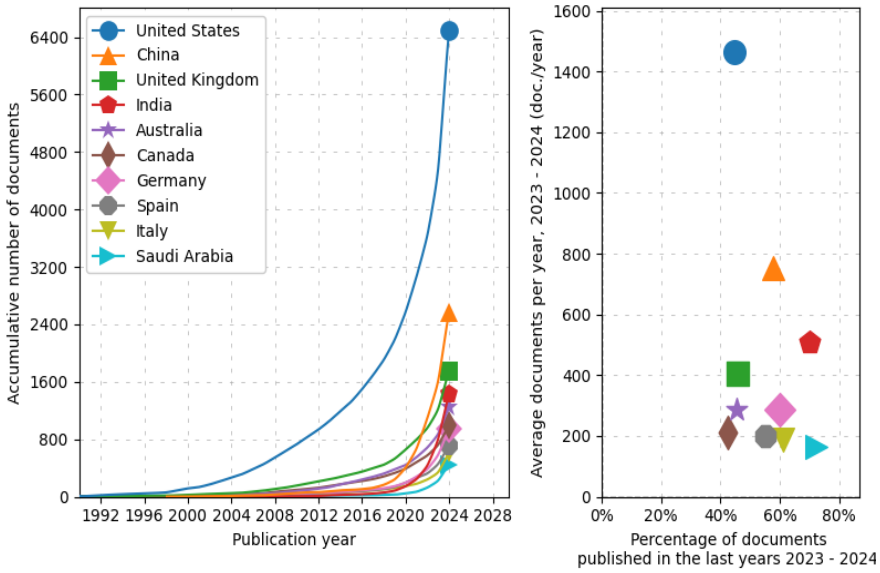
Source: Author, using ScientoPy 2.1.3

Fig. 4. Top ten theories are used underpinning AI in education research

3.5 Productive Countries

The analysis of the data presented in Figure 5 indicates that the United States is at the forefront, boasting a staggering total of 6,565 publications, which constitutes the largest share of research output in AI in education globally. The cumulative number of documents has shown remarkable growth over the years, particularly accelerating since 2010, highlighting the U.S. as a pivotal hub for innovation and research in educational technologies**.** China follows as the second-largest contributor, with 2,600 publications. The country has experienced rapid growth in this area, with a notable increase in the number of publications, particularly in recent years. This trend reflects China's growing investment in education and technology, positioning it as a key player in the global AI education landscape. The United Kingdom ranks third with 1,766 publications. The steady output of research from the U.K. underscores its commitment to exploring the intersections of AI and education, with significant contributions to theoretical frameworks and practical applications**.** India is also making substantial strides, with 1,448 publications, ranking fourth in the field. The country's growing emphasis on technology in education is evident in its increasing number of publications, particularly in recent years, indicating an evolving landscape of educational research. Australia and Canada follow, with 1,256 and 997 publications, respectively. Both countries demonstrate a strong commitment to integrating AI technologies into educational practices, contributing significantly to the body of knowledge in this area. Germany and Spain also contribute to the research output, with 954 and 720 publications, respectively. These countries are actively engaging in discussions surrounding the implementation of AI in education, reflecting a broader European interest in educational technology**.** Italy and Saudi Arabia round out the top ten, with 616 and 456 publications, respectively. While their contributions are smaller in comparison, they indicate a growing recognition

of the importance of AI in enhancing educational methodologies. The data also reflects a dynamic and expanding global interest in AI in education, with the United States leading the charge, followed by significant contributions from China, the United Kingdom, and India, among others. This trend not only highlights the increasing recognition of AI's potential in transforming educational practices but also points to a collaborative global effort to harness technology for improved learning outcomes.



Source: Author, using ScientoPy 2.1.3

Fig. 5. The top ten countries leading AI in education

3.6 The Most Cited Articles

According to the Table 2, the article with the highest citation count is Artificial Intelligence (AI): Multidisciplinary Perspectives on Emerging Challenges, Opportunities, and Agenda for Research, Practice, and Policy by Dwivedi *et al.,* [11], has 1,799 citations and provides a roadmap for AI research and policy development across education, business, and healthcare. Another influential study by Dwivedi *et al.,* [12], So What if ChatGPT Wrote It?, with 1,681 citations, explores the rise of generative AI, including ChatGPT, and its impact on research, education, and ethics. Similarly, Performance of ChatGPT on USMLE by Kung *et al.,* [19], has 1,636 citations assesses ChatGPT's ability to assist in medical education. In the field of higher education, Zawacki-Richter *et al.,* [15], systematic review has 1,480 citations evaluates AI applications in learning environments while highlighting the lack of educator involvement in AI research. Natural Pedagogy by Csibra and Gergely [10] with 1,255 citations discusses human learning behaviours, influencing AI-driven educational models. Michael's [21], work on active learning has 1,056 citations provides evidence supporting student engagement strategies that align with AI-powered education. Several articles on ChatGPT have also gained significant attention, such as Ray [23], has 1,050 citations, which reviews ChatGPT's strengths, biases, and applications, and Sallam [24], has 1,022 citations, which explores its role in healthcare education. Additionally, Maenner *et al.,* [23], has 978 citations analyze autism spectrum disorder prevalence, providing valuable data for AI-driven diagnoses. Lastly, Chen *et al.,* [9], has 882 citations review AI's transformative role in education, emphasizing personalized learning and AI-based assessments. These articles collectively highlight the increasing focus on AI in education, ChatGPT's applications, and systematic reviews on AI's role in cognitive learning and medical advancements.

Table 2
Top ten most cited sources

Authors	Title	Citation	Sources	Year
Dwivedi Y.K., Hughes L., Ismagilova E., Aarts G., Coombs C., Crick T., Duan Y., Dwivedi R., Edwards J., Eirug A., Galanos V., Ilavarasan P.V., Janssen M., Jones P., Kar A.K., Kizgin H., Kronemann B., Lal B., Lucini B.,	Artificial Intelligence (AI): Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy	1799	Scopus	2021
Dwivedi Y.K., Kshetri N., Hughes L., Slade E.L., Jeyaraj A., Kar A.K., Baabdullah A.M., Koohang A., Raghavan V., Ahuja M., Albanna H., Albashrawi M.A., Al-Busaidi A.S., Balakrishnan J., Barlette Y., Basu S., Bose I., Brooks L., Buhalis D., Carter L., Chowdhury S., Crick T., Cunningham S.W., Davies G.H., Davison R.M., De R., Dennehy D., Duan Y., Dubey R., Dwivedi R., Edwards J.S., Flavian C., Gauld R., Grover V., Hu M.C., Janssen M., Jones P., Junglas I., Khorana S., Kraus S., Larsen K.R., Latreille P., Laumer S., Malik F.T., Mardani A., Mariani M., Mithas S., Mogaji E., Nord J.H., O'Connor S., Okumus F., Pagani M., Pandey N., Papagiannidis S., Pappas I.O., Pathak N., Pries-Heje J., Raman R., Rana N.P., Rehm S.V., Ribeiro-Navarrete S., Richter A., Rowe F., Sarker S., Stahl B.C., Tiwari M.K., van der Aalst W., Venkatesh V., Viglia G., Wade M., Walton P., Wirtz J., Wright R.	-So what if ChatGPT wrote it? Multidisciplinary perspectives on opportunities, challenges and implications of generative conversational AI for research, practice and policy	1681	Scopus	2023
Kung T.H., Cheatham M., Medenilla A., Sillos C., De Leon L., Elepano C., Madriaga M., Aggabao R., Diaz-Candido G., Maningo J., Tseng V.	Performance of ChatGPT on USMLE: Potential for AI-assisted medical education using large language models	1636	Scopus	2023
Zawacki-Richter O., Marin V.I., Bond M., Gouverneur F.	Systematic review of research on artificial intelligence applications in higher education - where are the educators?	1480	Scopus	2019
Csibra, G., Gergely, G.	Natural pedagogy	1255	WoS	2009
Michael, J.	Where's the evidence that active learning works?	1056	WoS	2006
Ray P.P.	ChatGPT: A comprehensive review on background, applications, key challenges, bias, ethics, limitations and future scope	1050	Scopus	2023
Sallam, M.	ChatGPT Utility in Healthcare Education, Research, and Practice: Systematic Review on the Promising Perspectives and Valid Concerns	1022	WoS	2023
Maenner M.J., Warren Z., Williams A.R., Amoakohene E., Bakian A.V., Bilder D.A., Durkin M.S., Fitzgerald R.T., Furnier S.M., Hughes M.M., Ladd-Acosta C.M., McArthur	Prevalence and Characteristics of Autism Spectrum Disorder Among Children Aged 8 Years Autism and Developmental	978	Scopus	2023

D., Pas E.T., Salinas A., Vehorn A., Williams S., Esler A., Grzybowski A., Hall-Lande J., Nguyen R.H.N., Pierce K., Zahorodny W., Hudson A., Hallas L., Mancilla K.C., Patrick M., Shenouda J., Sidwell K., DiRienzo M., Gutierrez J., Spivey M.H., Lopez M., Pettygrove S., Schwenk Y.D., Washington A., Shaw K.A.	Disabilities Monitoring Network, 11 Sites, United States, 2020			
Chen, L.J., Chen, P.P., Lin, Z.J.	Artificial Intelligence in Education: A Review	882	WoS	2020

Source: Author, using ScientoPy 2.1.3

4. Discussion

Given the scarcity of prior studies examining AI in education through a bibliometric lens, this research aims to provide a comprehensive analysis of existing literature using the ScientoPy analysis tool. This approach will significantly contribute to future research in the field. Specifically, the study investigates the current landscape of global research on AI in education. Furthermore, it offers insights into academic collaboration by employing visualization techniques to illustrate the interconnections among studies and researchers within this domain, based on an analysis of the most frequently cited papers. The application of the ScientoPy analysis tool in bibliometric studies is vital for a thorough understanding of AI in education research. Researchers can explore various patterns in scientific discourse surrounding AI in education, including trends in published studies, prevalent topics, and the sources of these publications. This includes categorizing document types and identifying countries that make substantial contributions to AI in education research. Consequently, employing bibliometric methods in AI in education research provides numerous advantages, such as identifying current trends and subjects deserving further investigation, as well as uncovering new and innovative pathways for future studies.

The findings of this research a remarkable upward trajectory, particularly from 2020 onward, as evidenced by the sharp increase in publications that reached nearly 6,000 documents by 2024. As illustrated in Figure 1, the graph shows that prior to 2020, the number of publications was relatively low, with fewer than 1,000 documents published across both Scopus and Web of Science (WoS), highlighting a growing interest in this field. Notable shifts in research focus have emerged, transitioning from theoretical frameworks and basic AI concepts to practical applications, such as intelligent tutoring systems, chatbots, and personalized learning experiences. Methodologically, the field has evolved to incorporate advanced techniques, including machine learning and data analytics, along with interdisciplinary approaches that combine insights from education, computer science, psychology, and data science. Several factors have influenced this rapid evolution, including significant technological advancements that enable the exploration of more complex applications, increased funding and policy support for educational technology, and a growing demand for personalized learning experiences tailored to diverse student needs. Additionally, the heightened public awareness and acceptance of AI's potential to enhance educational outcomes, along with the COVID-19 pandemic's role in accelerating the adoption of online learning technologies, have collectively driven researchers to delve deeper into this transformative area. Consequently, the current landscape of AI in education reflects not only a thriving research environment but also a critical intersection of technology and pedagogy, poised for further exploration and development.

Examining the prominent source titles depicted in Figure 2, the ACM International Conference Proceeding Series is the most prolific publication venue, with 488 documents, followed by Lecture Notes in Networks and Systems, CEUR Workshop Proceedings, Communications in Computer and

Information Science, and Education and Information Technologies. These sources indicate a strong focus on computer science, engineering, and education-related research. While the dataset does not provide explicit impact factors, some journals such as Education and Information Technologies and Sustainability are known for their high citation rates and indexing in Scopus and Web of Science. In contrast, ACM International Conference Proceeding Series and CEUR Workshop Proceedings are highly regarded in the computing community but primarily publish conference papers, which may have lower impact factors compared to peer-reviewed journals. A key trend observed is the increasing number of publications from 2023 to 2024, with journals like Education and Information Technologies (91%) and Lecture Notes in Networks and Systems (86%) showing a high percentage of recent articles. This suggests growing interest in technology-driven education and networking research. The dominance of conference proceedings ACM and CEUR highlights the significance of conferences in rapidly evolving fields like computer science. Additionally, the presence of Sustainability and Sport Education and Society in the dataset reflects an expanding research focus that integrates technology with social and environmental sciences. The data also suggests a dynamic research landscape with increasing publication volumes in interdisciplinary domains.

The bibliometric analysis in Figure 3 reveals a significant insight into the current research landscape. The most prevalent topics include Artificial Intelligence (AI), which comprises 74% of the literature, followed by Education at 64%, and notable mentions of ChatGPT and Machine Learning at 100% and 62%, respectively. Pedagogy emerges as a critical area with 71% of research focusing on how AI influences teaching methodologies, while Higher Education accounts for 78% of the publications, indicating a strong emphasis on institutional applications. These themes underscore the transformative potential of AI in enhancing learning outcomes through personalized experiences and necessitate the development of curricula that effectively integrate AI technologies. Moreover, there is a pressing need for professional development programs to train educators in the use of AI tools, along with a growing discourse on ethical considerations surrounding AI applications, particularly tools like ChatGPT, which prompt discussions about responsible usage in educational settings.

While artificial intelligence (AI) offers transformative potential in education, a number of ethical concerns must be addressed to ensure its responsible implementation. One of the primary issues is algorithmic bias; AI-driven educational tools frequently mirror the biases embedded in their training data, potentially exacerbating existing social inequalities. Biases inherent in data sources can persist and escalate through algorithmic processes, becoming ingrained within the systems that deploy them, leading to entrenched disparities in educational outcomes [14]. Furthermore, as education increasingly relies on AI-powered student assessments, issues related to fairness, transparency, and accountability have come to the forefront. The opacity of AI decision-making processes creates significant challenges for educators and students who may find it difficult to understand how AI systems arrive at their recommendations or grades. There is a pressing need to enhance the transparency of these systems to empower users to make informed decisions based on AI outputs [26]. Moreover, AI applications in education routinely gather vast amounts of student data, which heightens privacy and security concerns among stakeholders. The potential for misuse or exposure of sensitive student information underscores the necessity for strong regulatory frameworks and robust policies to safeguard individual privacy [5,16]. Absent these measures, the risk of cyber threats and other forms of data compromise remains alarmingly high. To effectively confront these ethical dilemmas, a multi-faceted approach is required. This includes implementing stronger regulatory oversight, adhering to ethical design principles in developing AI technologies, and promoting greater transparency in the evolution and deployment of AI systems in educational contexts [16]. The integration of ethical considerations alongside technological development is vital in fostering an educational environment that is both innovative and equitable.

Emerging topics such as the applications of ChatGPT and generative AI are gaining traction but remain underexplored, warranting further investigation into their effectiveness and biases. Additionally, the integration of AI in K-12 education is an area ripe for study, along with longitudinal research to assess the long-term impacts of AI in educational environments. Finally, understanding how AI tools can be culturally and contextually adapted remains crucial, as this exploration will enhance the relevance and efficacy of AI in diverse educational settings. Overall, while the current literature reflects a robust interest in AI's role in education, several emerging and understudied topics require deeper exploration to ensure that AI integration is both effective and ethical.

The findings depicted in Figure 4 show that Self-Determination Theory (SDT) being particularly influential, as indicated by the 61% of total documents published under this framework. This highlights its relevance in understanding how psychological needs drive student motivation and engagement in AI-enhanced learning environments. Critical Theory (46%) emphasizes social justice and equity in the application of AI in education, while Activity Theory (64%) focuses on the contextual interactions among various elements in educational settings, enriching our understanding of AI integration in learning. To advance research, it is recommended that scholars expand theoretical frameworks by exploring intersections between multiple theories, such as combining SDT with Critical Theory to address both motivation and equity. Longitudinal studies are necessary to assess the long-term effects of AI on learning and teaching practices, while interdisciplinary collaboration among educators, psychologists, and technologists will help create comprehensive AI educational tools. For policymakers, the incorporation of AI literacy into school curricula is essential, alongside support for professional development programs that equip educators to integrate AI tools effectively. Equity-focused policies should ensure all students have access to AI technologies, particularly for underrepresented communities, and ethical guidelines must be established to address data privacy, bias, and inequalities. By leveraging these theoretical insights and practical recommendations, researchers and policymakers can collaboratively create an educational landscape that is technologically advanced, equitable, inclusive, and conducive to effective learning.

The analysis of leading countries in AI in education research highlights the significant contributions made by the United States, China, the United Kingdom, India, and Australia. Figure 5 also indicates that the United States leads with 6,565 publications, benefiting from a robust research infrastructure, substantial funding from federal agencies, and the presence of major AI research labs like OpenAI and Google AI. China follows with 2,600 publications, driven by strong government support and strategic policies that emphasize AI applications in education, along with the availability of large-scale data from digital platforms. The United Kingdom, with 1,766 publications, excels due to its esteemed academic institutions and focus on AI ethics, bolstered by funding from UK Research and Innovation. India, contributing 1,448 publications, is experiencing growth fueled by a high demand for AI educational tools and government initiatives like the National Education Policy (NEP 2020). Australia, with 1,256 publications, emphasizes EdTech startups and AI solutions tailored for remote learning, supported by initiatives from the Australian Research Council. While Western countries generally prioritize AI ethics and personalized learning, China and India focus on large-scale implementations to meet the needs of their vast student populations, and European nations explore adaptive learning and multilingual education tools. In this case, the U.S. and China dominate the field, yet other countries contribute uniquely based on their educational contexts and requirements.

Meanwhile, Table 2 identifies several highly cited articles that have significantly impacted subsequent research and practice in the field. Among these, Artificial Intelligence (AI): Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy by Dwivedi *et al.,* [11], leads with 1799 citations, establishing a foundational agenda for future AI research in education. Following closely are articles like So what if ChatGPT wrote it? [12] has 1681 citation and Performance of ChatGPT on USMLE [19] has 1636 citations, which

have spurred dialogue about ethical considerations and practical applications of generative AI tools like ChatGPT in educational settings. The systematic review by Zawacki-Richter *et al.,* [25], emphasizes the necessity for educators to adapt their teaching methods to integrate AI, influencing curriculum development and educational policies. The themes covered by these influential articles include the need for a multidisciplinary approach to understanding AI's role in education, the implications of generative AI on learning experiences, the performance evaluation of AI tools, challenges in AI integration, and the call for pedagogical innovation that leverages AI technologies. Collectively, these articles underscore significant trends and challenges, laying the groundwork for ongoing discourse and research that explores AI's transformative potential within educational contexts.

5. Conclusions

This bibliometric analysis of AI in education reveals significant insights into the evolution of research in this rapidly growing field. Key findings include a marked increase in publications post-2020, with the United States, China, and the United Kingdom leading the way in research output. Prominent journals such as the ACM International Conference Proceeding Series and Education and Information Technologies have emerged as key platforms for disseminating research. Common research topics identified include the applications of intelligent tutoring systems, machine learning, and generative AI tools like ChatGPT. Additionally, the analysis highlighted several highly cited articles that are instrumental in shaping the discourse around AI in education. The implications of these findings are profound for both research and practice. Future research directions should focus on exploring understudied areas, such as the ethical implications of AI in K-12 education and the integration of AI technologies in diverse learning environments. Additionally, future studies also should emphasize comparative research on AI adoption in different educational contexts across various regions and educational levels. While some countries have rapidly integrated AI into higher education, others remain in the early stages of adoption, creating a disparity in AI's effectiveness and impact. Comparative studies could explore factors such as government policies, cultural attitudes toward AI, infrastructure availability, and educator preparedness, helping to identify best practices and potential barriers to AI-driven learning. A cross-national analysis would provide valuable insights into how AI can be adapted to diverse educational systems and contribute to a more equitable and effective implementation worldwide. There is a critical need for interdisciplinary collaboration, as the complexities of AI in education require insights from various fields, including psychology, data science, and educational technology. Interdisciplinary collaboration is essential for a holistic understanding of AI in education. Psychology can contribute insights into cognitive load, motivation, and personalized learning strategies, enabling AI systems to better adapt to student needs. Data science plays a pivotal role in analysing vast datasets, ensuring AI algorithms are fair, unbiased, and transparent in their decision-making processes. Meanwhile, educational technology experts bridge the gap between theoretical AI applications and practical implementation in classrooms. Additionally, the involvement of ethics and policy researchers is crucial to address concerns regarding data privacy, security, and the responsible use of AI. By fostering collaboration across these domains, future research can drive the development of AI-powered educational tools that are not only effective but also ethically and pedagogically sound.

This bibliometric analysis contributes significantly to the understanding of AI in education by providing a comprehensive overview of existing research, identifying influential researchers, and highlighting emerging themes. However, it is important to acknowledge its limitations, such as potential biases in data collection and the constraints of available literature, which may affect the generalizability of the findings. Looking ahead, there is a pressing need for more comparative studies

across different cultures and countries to better understand how cultural contexts influence the implementation and effectiveness of AI in educational settings. Furthermore, incorporating qualitative data into future bibliometric analyses could enrich the understanding of the quantitative findings, providing deeper insights through detailed author interviews and content analyses of key texts. While bibliometric and quantitative analyses offer valuable insights into research trends and AI adoption in education, integrating qualitative methodologies can provide a more nuanced understanding of AI's real-world impact. Future studies could benefit from in-depth interviews with educators and students to capture their lived experiences, challenges, and perceptions regarding AI-powered learning tools. Additionally, case studies of AI implementation in various educational settings could offer contextualized insights into best practices and barriers to adoption. Ethnographic research and discourse analysis of AI-related academic discussions could further reveal underlying attitudes and institutional policies shaping AI integration. By combining qualitative and quantitative approaches, future research can present a more comprehensive and human centred perspective on the evolving role of AI in education. By addressing these gaps, the research community can better harness AI's potential to transform education in a culturally responsive and effective manner.

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