

Artificial intelligence and education: A bibliometric analysis of global research trends and future directions



Abdul Hayy Haziq Mohamad^{ab}✉ | Rossazana Ab-Rahim^c  | Armstrong Ighodalo Omoregie^d  |
Muhammad Hafiz Bin Muhammad Hisham^{ab} 

^aSchool of Business and Administration, University of Technology Sarawak, Sibul, Sarawak, Malaysia.

^bCentre on Technological Readiness and Innovation in Business Technopreneurship, University of Technology Sarawak, Sibul, Sarawak, Malaysia.

^cFaculty of Economics and Business, Universiti Malaysia Sarawak, Kota Samarahan, Sarawak, Malaysia.

^dSchool of Built Environment, University of Technology Sarawak, Sibul, Sarawak, Malaysia.

Abstract This study offers a comprehensive bibliometric analysis of the intersection between artificial intelligence (AI) and education, with a particular emphasis on research trends, geographical distribution, and thematic developments spanning the period from 2000 to 2023. Drawing upon data from Scopus and the Web of Science (WoS), the analysis employed specialised tools, namely ScientoPy and VOSviewer, to identify temporal dynamics, collaborative patterns, and emerging areas of scholarly focus. A significant rise in publications during 2022–2023 signals the increasing impact of AI technologies on educational transformation and reflects growing academic interest in the integration of intelligent systems within teaching and learning processes. The geographical analysis highlights the leading roles of China, the United States, and India in advancing AI applications in education, underscoring the influence of national strategies and strong research ecosystems in driving innovation. The findings suggest that future research should examine the development of hyper-personalised learning environments and the ethical deployment of AI to enhance inclusivity and sustainability in education. As AI systems become increasingly embedded in educational platforms, issues of equity, transparency, and governance require closer scrutiny to ensure responsible innovation. VOSviewer mapping reveals that the term “artificial intelligence” is closely linked to key areas such as “education,” “higher education,” and “machine learning,” illustrating AI’s central function in enabling adaptive, personalised, and effective learning systems. Overall, this analysis contributes valuable insights into the progression of AI in educational contexts and establishes a basis for future exploration and implementation, offering evidence-based perspectives for educators, researchers, and policymakers navigating this evolving field.

Keywords: adaptive learning, digital transformation, generative AI, online learning, immersive technologies

1. Introduction

The transformative potential of artificial intelligence (AI) in education has attracted substantial attention from academics, policymakers, and education practitioners over the past decade. As a foundational element of the Fourth Industrial Revolution (IR4.0), AI technologies have penetrated multiple facets of the education sector, reshaping conventional pedagogical models, enriching learning experiences, streamlining administrative operations, and revolutionising instructional methodologies through personalised and adaptive learning approaches (Al-Maskari, 2024; Atibuni et al., 2022; Singaram et al., 2023). AI-driven tools enable differentiated teaching by tailoring content delivery to individual learning styles, tracking learner progress, and conducting performance evaluations (Strielkowski et al., 2024). According to Huang et al. (2023) and Almusaed et al. (2023), the emergence of interactive AI in educational settings fosters greater student motivation and engagement, while allowing educators to focus on more innovative and interactive teaching strategies. Moreover, AI enhances remote and hybrid learning environments through intelligent content management and virtual teaching assistants (Lin and Chen, 2024), thus broadening educational access and fostering inclusivity for learners across diverse global contexts (Atibuni et al., 2022; Verma et al., 2023).

In recent years, educational institutions across the world have increasingly incorporated AI-based technologies such as intelligent tutoring systems, adaptive learning platforms, and automated assessment tools (Demartini et al., 2024; Peters and Green, 2024; Khlaif et al., 2024). These developments support personalised learning pathways, promote data-informed decision-making, and improve access to quality education (Strielkowski et al., 2024; Liu et al., 2017). As a result, it is essential to understand the scope and depth of AI applications within education to advance both theoretical frameworks and practical implementation strategies (Järvelä et al., 2023). The use of AI in educational environments, particularly within the field of language learning, has been the focus of considerable academic inquiry in recent years (Bahroun et al., 2023). Numerous comparative reviews of



bibliometric studies have identified significant patterns, methodologies, and research outcomes that enhance the current understanding of AI's evolving role in the educational landscape.

The bibliometric study conducted by Kavitha (2024) highlights the growing volume of academic literature concerning the use of AI in educational contexts and emphasises the significance of recognising key scholars contributing to this field. In a similar manner, Rahman (2024) presented a comprehensive bibliometric and content-based analysis of AI applications in language learning, evaluating 606 documents published between 2017 and 2023. The outcomes of this study reflect the increasing importance of AI in enhancing language acquisition processes. Expanding upon this theme, Prahani et al. (2022) reviewed AI-related educational research over the past ten years by analysing 457 publications indexed in Scopus. This complements the extensive bibliometric analysis conducted by Durak (2024), who examined 1,726 academic papers from the Web of Science database covering the period 2013 to 2023, and highlighted evolving trends in publication and citation patterns across nations and institutions, while underscoring the collaborative nature of AI research in educational settings. The study by Batubara et al. (2024) similarly investigates the bibliometric characteristics of AI research in tertiary education using data from the Web of Science.

A study focusing specifically on AI-powered recommendation systems in online learning contexts highlighted the role of Learning Management Systems (LMS) in enabling AI-driven educational processes and noted the shift towards personalised learning models (Lutfiani et al., 2022). This observation is supported by the bibliometric mapping analysis carried out by Lubis (2024), which explored the application of AI in language education. Lubis's findings identified recurring themes such as personalised learning, mobile-assisted learning, and chatbot integration, pointing to an increased interest in how AI can function as a virtual assistant for language learners. The results from both studies illustrate the growing focus on AI's application in language learning and its ability to enhance learner engagement and support mechanisms. This contrasts with the bibliometric analysis conducted by Montalván (2024), which categorises the influence of AI in higher education across four thematic axes. The study traces the development of research trajectories over time and applies established bibliometric laws, such as those of Price and Lotka, to assess scholarly productivity and the relative influence of contributors in this field. This methodological rigour is further mirrored in the work of Afzaal (2024), who provides a decade-long bibliometric mapping of AI integration in education, revealing prominent publication trends and the formation of collaborative research networks.

In more specialised fields, such as legal education, Mong (2024) investigates the intersection of AI and legal training by identifying research directions and trends from 1999 to 2024. Similarly, Wang (2024) examines the integration of AI into medical education, emphasising its transformative impact on teaching strategies and its potential to improve diagnostic training. Both studies underline the necessity for education systems to revise existing curricula to incorporate AI-related content, thereby aligning with the rapidly changing professional and technological landscapes. Other researchers also draw attention to the broader implications and future directions of AI in education, complementing the findings of Ciaccio (2024), who assesses AI's role in marine environmental monitoring. Additionally, studies specifically addressing mathematics education, such as that by Kaushik et al. (2021), identify distinctive research trends that highlight the promise of AI in enhancing STEM education outcomes. Their work contributes to the discourse by offering insights into effective methods for integrating AI tools into mathematics instruction to support innovative pedagogical practices.

In a wider context, the study by Hinojo-Lucena et al. (2019) identifies virtual tutoring as a key application of AI in higher education, with particular emphasis on its educational impact. These findings are in agreement with those of Ullrich et al. (2022), who highlight the growing use of AI for learning analytics and performance evaluation within modern education systems. Both studies highlight the transformative influence of AI technologies in advancing both instructional delivery and institutional management. The research by Montalván (2024) further examines how AI contributes to administrative optimisation, particularly in relation to enrolment coordination and academic planning. The convergence of findings across these studies reveals a global shift towards the adoption of AI to improve both teaching practices and operational efficiency across educational ecosystems. This shift is reinforced by the bibliometric work of Afzaal (2024), who contextualises a decade-long trend of AI integration in education, documenting a marked increase in scholarly output and growing academic interest in the field. These observations are supported by Akhmadiev (2023), who provides a descriptive bibliometric overview focused on AI in science education, outlining publication frequencies and identifying leading scholars within the domain.

Furthermore, the study by Wu (2024) on AI chatbot usage in language education demonstrates a specific application of AI that has gained substantial momentum in recent years. Wu's analysis aligns with the work of Husaeni (2022), who reviews the strengths and limitations of AI chatbots in science and engineering education, offering a more nuanced perspective on the role of AI in supporting autonomous and self-paced learning. Lastly, the work of Castro (2024), which examines pedagogical strategies that incorporate AI tools, adds further depth to the ongoing discourse by evaluating how AI is being integrated into instructional design. When considered alongside the insights offered by the aforementioned studies, Castro's analysis contributes to a comprehensive understanding of the current state of AI in education, while also identifying the key opportunities and challenges that must be addressed moving forward.

Although numerous prior studies have examined AI in educational contexts, this paper offers a comprehensive bibliometric investigation of research on AI and education, specifically analysing the development and direction of AI-focused educational research between 2000 and 2023, with particular emphasis on the two most recent years (2022–2023). The novelty of this study

lies in its focus on emerging research trends using the most current bibliometric data available. In line with this, the study sets out the following objectives:

- i) To analyse the future trends of AI in the context of education using bibliometric data from the Web of Science and Scopus databases from 2000 to 2023.
- ii) To evaluate global contributions to AI-driven education, with particular attention to leading countries during the period 2022 to 2023.
- iii) To examine the surge in AI applications in education during 2022 to 2023 and assess their transformative implications.
- iv) To identify the ten most highly cited publications on AI in education.
- v) To explore recent keyword associations in AI and education research through VOSviewer-based network mapping.

2. Methods

This study employed advanced bibliometric methodologies and specialised software tools, notably ScientoPy and VOSviewer. ScientoPy played a crucial role in identifying temporal research trends by enabling detailed analysis of publication metrics, including keyword frequency and evolution over time, thematic development, and author contributions. This analytical capability allowed for a more nuanced understanding of how the domain of e-learning intersects with cultural and traditional contexts, uncovering emerging research topics and highlighting shifts in scholarly focus across different time periods. In contrast, VOSviewer substantially enhanced the analysis by supporting the construction and visualisation of complex bibliometric networks (Mohamad et al., 2024a). It was particularly effective in mapping co-authorship patterns, citation structures, and keyword co-occurrence clusters, offering a comprehensive overview of collaborative relationships and the intellectual framework of the field (Mohamad and Ab-Rahim, 2025). The software's capacity to generate visually intuitive network diagrams enabled the identification of key nodes and linkages, including influential researchers, widely cited publications, and prominent thematic areas.

The integration of these tools provided a multidimensional analytical perspective, combining quantitative bibliometric indicators with qualitative interpretations based on visual patterns and relational structures. This comprehensive approach not only enhanced the clarity and interpretability of the findings but also contributed to a deeper understanding of the complex interconnections within the research landscape, yielding meaningful insights into the evolving discourse on e-learning in relation to culture and tradition. The application of such sophisticated methodological tools highlights the value of adopting state-of-the-art techniques in bibliometric research to achieve improved analytical accuracy and richer interpretive outcomes.

2.1. Data string and pre-processing analysis

This study draws upon two prominent academic databases, Scopus and Web of Science (WoS), to undertake a comprehensive bibliometric analysis of the research landscape at the intersection of artificial intelligence (AI) and education. The dataset was extracted on 28 October 2024 to capture the most recent research output and prevailing trends. The analysis spans a 25-year period, from 2000 to 2024, offering valuable insights into how scholarly interest in this dynamic and evolving field has developed over time. The search query was meticulously designed to retrieve the most relevant publications, using the following string: TITLE ("education" AND "AI" OR "Artificial Intelligence") AND PUBYEAR > 1999 AND PUBYEAR < 2025 AND (LIMIT-TO(EXACTKEYWORD, "Artificial Intelligence") OR LIMIT-TO(EXACTKEYWORD, "Education")). This research focused solely on the "title" field, and the carefully crafted query ensured the inclusion of publications that explicitly address AI and education as core themes, while excluding less pertinent studies. The inclusion criteria emphasised the exact keywords "Artificial Intelligence" and "Education", thereby enhancing the dataset's precision and relevance for subsequent analysis.

The data cleaning and preprocessing phase played a vital role in ensuring that the findings of the bibliometric analysis are reliable, valid, and reproducible. By systematically removing duplicate entries and standardising the dataset, the analysis was able to more accurately reflect trends, identify key contributors, and trace the thematic evolution within the domain of AI and education. The rigorous procedures adopted in this phase underline the importance of methodological transparency and accuracy in bibliometric studies, ensuring that the results provide a credible basis for future research (Mohamad et al., 2024b).

Table 1 indicates the initial dataset, compiled from Scopus and WoS, consisted of 2,881 records and formed the foundation for the analysis. An automatic filtering process based on document type led to the exclusion of 312 records, amounting to 10.80 percent of the dataset. This step, which likely removed non-research items such as editorials, conference abstracts, or news articles, was essential to ensure the relevance and academic quality of the remaining data. Following this filtering stage, the dataset was reduced to 2,569 records, representing a more targeted and scholarly relevant collection of research outputs.

A detailed examination of the source-specific distribution revealed that Scopus contributed a substantial majority, with 2,260 records (88.00 percent), while WoS provided 309 records (12.00 percent). This disparity reflects the broader coverage offered by Scopus, which is known for indexing a wide range of journals, particularly in applied, technical, and multidisciplinary domains. In contrast, WoS typically offers a more selective and curated indexing process. This distribution pattern suggests that the dataset is shaped significantly by Scopus's inclusivity, potentially providing a more comprehensive view of the research landscape.

The identification and removal of duplicate records was essential to preserve the accuracy and integrity of the analysis. A total of 199 duplicates were identified across both databases, representing 7.70 percent of the dataset after the initial filtering. This process ensured that each study was uniquely counted, thus avoiding the issue of double counting that could distort the bibliometric findings. The majority of duplicates were located within Scopus, amounting to 197 records (8.70 percent of its share), where as WoS contributed only 2 duplicates, accounting for a minimal 0.60 percent. After both filtering and de-duplication were completed, the final dataset consisted of 2,370 unique records. Of these, 2,063 were sourced from Scopus (87.00 percent), and 307 from WoS (13.00 percent), forming the refined corpus for the subsequent bibliometric analysis.

Table 1 Data integration and duplicates exclusion.

Data Pre-Processing Output	Information	Number	Percentage (%)
Initial Results	Total papers from Raw data (Scopus and WoS)	2881	-
	Omitted papers by document type (Automatic type-filter publication)	312	10.80
	Total papers after omitted papers removed (Total publications after selection)	2569	-
	Publications in WoS	309	12.00
	Publications in Scopus	2260	88.00
Duplicate Removal Results	Duplicated publications in both databases	199	7.70
	Duplicated publications from WoS	2	0.60
	Duplicated publications from Scopus	197	8.70
Final Results	Total papers after removing duplicates	2370	-
	Final selected paper from WoS	307	13.00
	Final selected paper from Scopus	2063	87.00

Source: Scopus and WoS databases.

3. Results and Discussion

The subject classification, as shown in Figure 1, highlights the diverse disciplinary contributions to research on "education" and "artificial intelligence" (AI). The findings reveal the extent to which various academic fields have engaged with this evolving research area, particularly over the last two years (2022–2023), reflecting the interdisciplinary nature and broad impact of AI in educational contexts. Education and educational research emerge as the dominant category, with 72 percent of its total publications produced between 2022 and 2023. This prominence underscores the central role of education as both a primary subject and a key application area for AI (Prahani et al., 2022). Researchers in this discipline focus on AI-driven instructional tools, adaptive learning systems, and curriculum innovation to support personalised learning and improve educational outcomes. The sharp increase in research activity in recent years signals the growing application of AI to address pedagogical challenges, including inclusivity, digital literacy, and equitable access to quality education worldwide (Nedungadi et al., 2024).

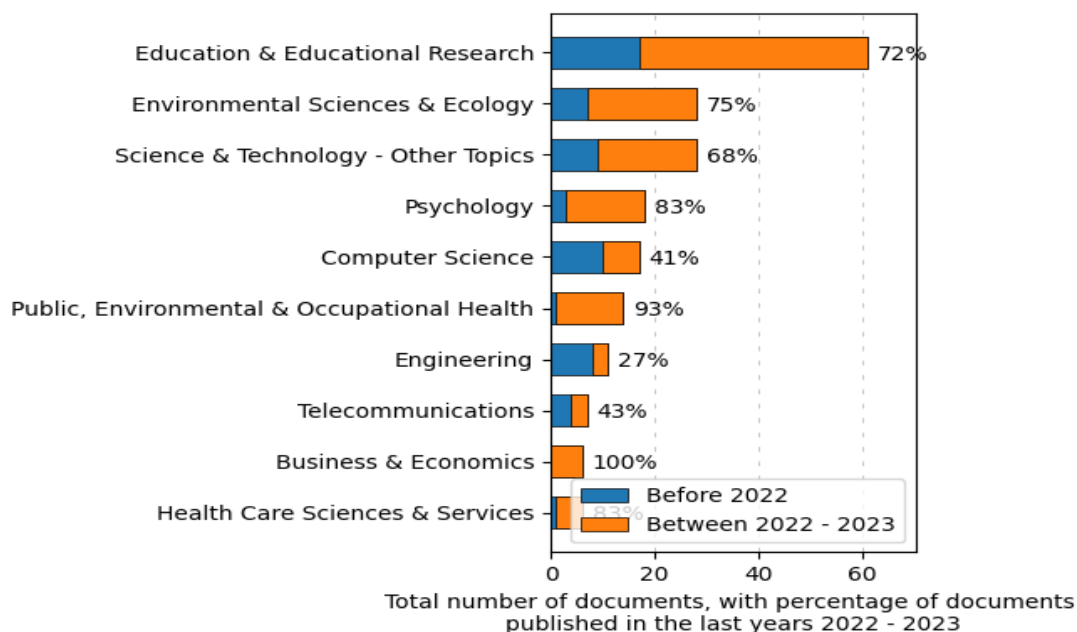


Figure 1 AI education subject(s). Source: Scopus and WoS databases.

The significant contribution from the fields of environmental sciences and ecology further demonstrates the expanding role of AI in promoting sustainability through education. This observation aligns with findings by Habila et al. (2023) and Bolón-Canedo et al. (2024), who investigate the role of AI in enhancing environmental literacy, climate change education, and ecological awareness. This category represents a notable share of scholarly output, with 68 percent of the documents published within the last two years, and includes studies examining the integration of AI into science and technology education. AI technologies such as machine learning, robotics, and augmented reality (AR) are increasingly embedded in science curricula to improve students' understanding of complex scientific concepts.

A similar trend is observed in the discipline of psychology, where 83 percent of publications were produced between 2022 and 2023, indicating a heightened focus on the role of AI in shaping learning behaviours and cognitive processes. Researchers in this field explore the psychological dimensions of AI in education, including its effects on student motivation, learning anxiety, and engagement with digital learning tools. In the domain of business and economics, a remarkable 100 percent growth was recorded in the last two years, pointing to a growing interest in AI applications related to workforce development, skills training, and the economics of education. Research in this category focuses on the role of AI in bridging skill gaps, enhancing employability, and advancing human capital development in alignment with ongoing technological progress.

The timeline analysis depicted in Figure 2 illustrates the publication trends and thematic evolution of research concerning "education" and "artificial intelligence" (AI) between 2000 and 2023. The findings reveal a substantial increase in scholarly output in recent years, reflecting a growing interest in the transformative potential of AI within education systems. During the early phase (2000 to 2015), research activity in this area remained relatively limited, with fewer than ten publications per year. At this stage, the application of AI in education was largely exploratory, and the widespread implementation of such technologies was likely constrained by technological limitations. Research during this period primarily focused on foundational developments in educational computing and e-learning, reflecting the early integration of digital tools into teaching and learning practices. A marked shift occurred around 2016, initiating a sustained increase in publication volume. This shift coincided with significant advancements in AI technologies, including machine learning, natural language processing, and adaptive learning systems, and was accompanied by the more frequent appearance of keywords such as "e-learning", "artificial intelligence technologies", and "students" within the academic literature.

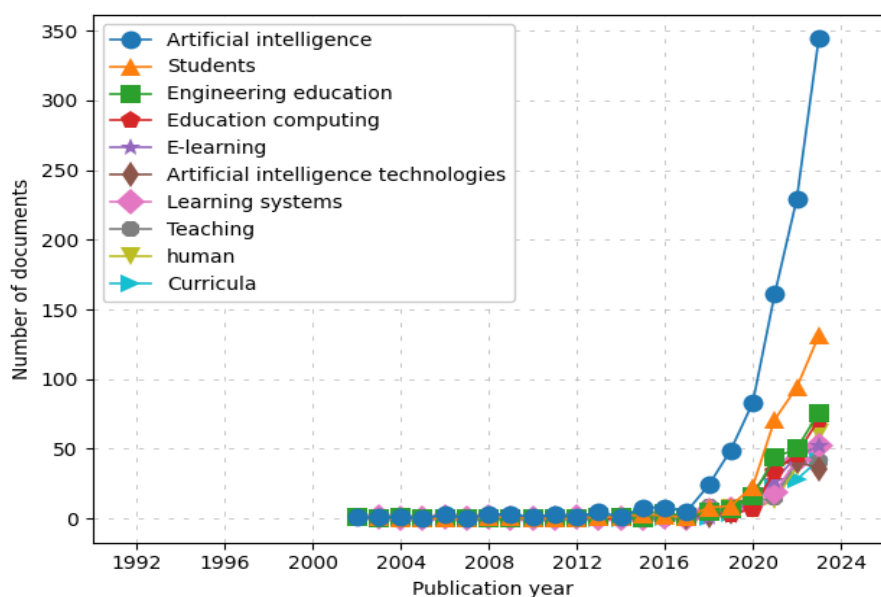


Figure 2 AI education evolution of research themes over time. *Source:* Scopus and WoS databases.

The period from 2020 to 2023 represents a notable turning point in terms of publication output, as demonstrated by a pronounced spike in the number of studies published. The term "artificial intelligence" emerged as the most dominant keyword, with more than 350 publications recorded in 2023 alone. According to Pantelimon et al. (2021) and Xie et al. (2020), this exceptional growth reflects the increasing impact of AI on education, driven by both rapid technological progress and global disruptions such as the COVID-19 pandemic. The upward trajectory in publication trends points to a growing scholarly consensus on the central role of AI in shaping contemporary educational practices. The emergence of themes such as "artificial intelligence technologies" and "learning systems" indicates a continuing focus on the development of advanced tools for adaptive instruction, data-driven performance analysis, and intelligent content delivery.

The geographical analysis presented in Figure 3 provides a comprehensive overview of global contributions to the research field focusing on "education" and artificial intelligence (AI). It highlights the substantial involvement of various countries in this rapidly evolving area of scholarship and identifies key trends in publication output over recent years, particularly during the 2022–

2023 period. China emerges as the leading contributor, accounting for 53 percent of all publications produced in the past two years. This dominant position reflects China's strategic prioritisation of AI as a transformative force within its education sector, a finding that aligns with previous research by Batubara et al. (2024), Prahani et al. (2022), and Song and Wang (2020). According to Wu et al. (2020) and Khanal et al. (2024), national initiatives such as the “Next Generation Artificial Intelligence Development Plan” have accelerated AI-related research and development, placing significant emphasis on the deployment of AI-powered platforms to support personalised and equitable education. China’s substantial research output reflects both the government’s sustained investment in technology-enhanced education and its focus on cultivating AI talent through the modernisation of educational curricula.

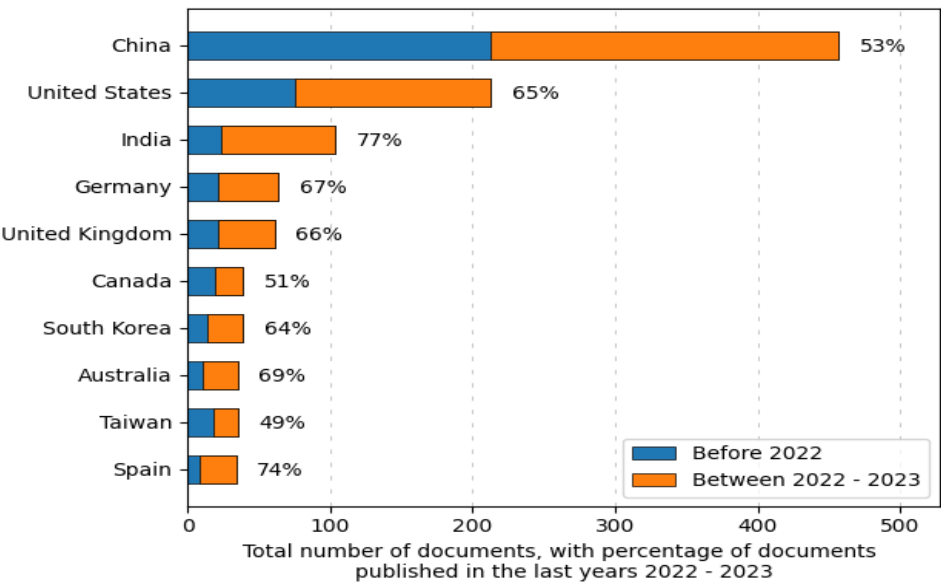


Figure 3 Geographical distribution of AI education publications. Source: Scopus and WoS databases.

Following China, the United States ranks as the second most prominent contributor, with 65 percent of its AI-in-education publications released during the 2022–2023 period. This strong performance is indicative of the United States' long-standing leadership in AI research and innovation, particularly in relation to educational technologies. The United States has played a pioneering role in the integration of AI tools, such as adaptive learning systems, intelligent tutoring platforms, and data-driven assessment mechanisms, into educational frameworks. Leading institutions, including world-renowned universities and research centres, continue to play a pivotal role in collaborative efforts aimed at leveraging AI to address learning disparities and meet the diverse needs of students.

A particularly significant trend is the rapid emergence of India, which recorded the highest proportion of publications within the last two years, at 77 percent. This surge in research output reflects an increasing recognition of AI’s role in mitigating educational inequalities within a highly diverse and populous context. National initiatives such as Digital India and AI-focused policy frameworks have promoted both academic and applied research in the domain of AI-driven education. India’s robust growth in this area demonstrates a clear strategic commitment to developing scalable and context-sensitive AI solutions, especially for rural and underserved educational environments. The results of this analysis suggest a consistent pattern, where countries with strong governmental backing, well-established research infrastructure, and dynamic technological innovation ecosystems dominate the global discourse on AI in education. While China and the United States remain central to this field, the remarkable rise of emerging economies such as India underscores the potential of AI to act as a catalyst for addressing longstanding educational challenges on a global scale.

Table 2 highlights the most highly cited publications on artificial intelligence in education, illustrating the considerable scholarly attention drawn by the integration of AI technologies into the educational domain. A detailed analysis of the ten most frequently cited papers uncovers major research directions, emerging thematic concerns, and influential debates that are currently shaping the intersection between AI and education in an increasingly digital-centric era. Among the most influential contributions is the study by Zawacki-Richter et al. (2019), which presents a systematic review that explores AI applications within higher education contexts across various settings and disciplines. The study’s primary contribution lies in its identification of a consistent lack of educator-led research, alongside a recommendation that teaching professionals take a more active role in directing how AI is embedded in educational systems. This argument continues to hold significance as educators today must navigate the integration of AI while maintaining instructional quality and pedagogical coherence. The second highly cited paper, by Chen et al. (2020), offers a broad review of AI technologies in education, including discussions on adaptive learning environments, automated assessment methods, and the development of virtual tutors. These AI innovations have become increasingly prevalent in practice, supporting tailored learning experiences and influencing how student progress is monitored and evaluated. The third most cited

study, by Popenici and Kerr (2017), investigates the influence of AI on both instructional delivery and learning, offering a critical perspective on how it reshapes the dynamics between teachers and learners. Their emphasis on ethical concerns, including privacy, transparency, and the risks of data misuse, resonates with current academic discussions around responsible AI use in learning platforms. The fourth paper, by Lim et al. (2023), addresses how educational institutions attempt to maximise the benefits of AI-supported learning while managing the risks of deepening educational inequality driven by automation and algorithmic decision-making.

Table 2 Highly cited papers on artificial intelligence in education.

Author(s)	Title	Source title	Cited
Zawacki-Richter et al. (2019)	Systematic review of research on artificial intelligence applications in higher education - where are the educators?	International Journal of Educational Technology in Higher Education	1070
Chen et al. (2020)	Artificial Intelligence in Education: A Review	IEEE ACCESS	780
Popenici and Kerr (2017)	Exploring the impact of artificial intelligence on teaching and learning in higher education	Research and Practice in Technology Enhanced Learning	616
Lim et al. (2023)	Generative AI and the future of education: Ragnarök or reformation? A paradoxical perspective from management educators	International Journal of Management Education	430
Roll & Wylie (2016)	Evolution and Revolution in Artificial Intelligence in Education	International Journal of Artificial Intelligence in Education	410
Hwang & Chien (2022)	Definition, roles, and potential research issues of the metaverse in education: An artificial intelligence perspective	Computers and Education: Artificial Intelligence	388
Chassignol et al. (2018)	Artificial Intelligence trends in education: A narrative overview	Procedia Computer Science	365
Eysenbach (2023)	The Role of ChatGPT, Generative Language Models, and Artificial Intelligence in Medical Education: A Conversation with ChatGPT and a Call for Papers	JMIR Medical Education	342
Cooper (2023)	Examining Science Education in ChatGPT: An Exploratory Study of Generative Artificial Intelligence	Journal Of Science Education and Technology	286
Chan (2023)	A comprehensive AI policy education framework for university teaching and learning	International Journal of Educational Technology in Higher Education	283

Source: Scopus and WoS databases.

Figure 4 illustrates the network visualisation of artificial intelligence (AI) and education, providing a dynamic and insightful representation of interconnected keywords and emerging trends within the field. This study utilised author keyword co-occurrence analysis combined with the full counting method, applying a minimum threshold of 15 keyword occurrences. As a result, 46 keywords met the threshold out of a total of 4,559. At the centre of the visualisation lies the term “artificial intelligence,” which is strongly connected to key domains such as “education,” “higher education,” and “machine learning.” These links reflect the central role of AI in shaping personalised, adaptive, and efficient educational systems. The Figure 4 also highlights several dominant trends that characterise the evolving landscape of AI in education. The prominence of “adaptive learning” and “learning analytics” underscores AI’s growing capacity to personalise educational content and monitor learning outcomes in real time.

Another significant observation from the visualisation is the increasing relevance of generative AI and technologies such as “chatbots.” These tools, exemplified by platforms like ChatGPT, are transforming the ways in which educators and learners engage with educational content (Liu et al., 2023). According to Salinas-Navarro et al. (2024), generative AI supports real-time feedback, fosters creative problem-solving, and provides dynamic support across formal and informal learning environments. As natural language processing technologies advance, these tools are expected to play an increasingly important role in supporting cross-cultural and multilingual education. The emergence of keywords such as “metaverse” and “virtual reality” as prominent nodes further illustrates the growing emphasis on immersive learning environments. By combining AI with virtual and augmented reality technologies, educators can offer experiential learning opportunities, including virtual laboratories, simulations, and fieldwork. These developments are particularly promising in disciplines that require practical experience, such as medicine, engineering, and environmental science (Preiksaitis & Rosel, 2023; Johri et al., 2023).

Ethical considerations also feature prominently within the visualisation, with terms such as “ethics,” “AI literacy,” and “challenges” signalling the importance of responsible AI integration in education. Concerns surrounding data privacy, algorithmic bias, and equitable access remain critical, particularly as educational institutions increasingly adopt AI-based technologies. To address these issues, there is growing attention to enhancing AI literacy among educators and students, ensuring they are equipped to understand and navigate the ethical and practical implications of AI use in education. The visualisation also captures

the enduring impact of the COVID-19 pandemic, with keywords like “online education” and “remote learning” prominently represented, reflecting the accelerated digital transformation of educational delivery during this period.

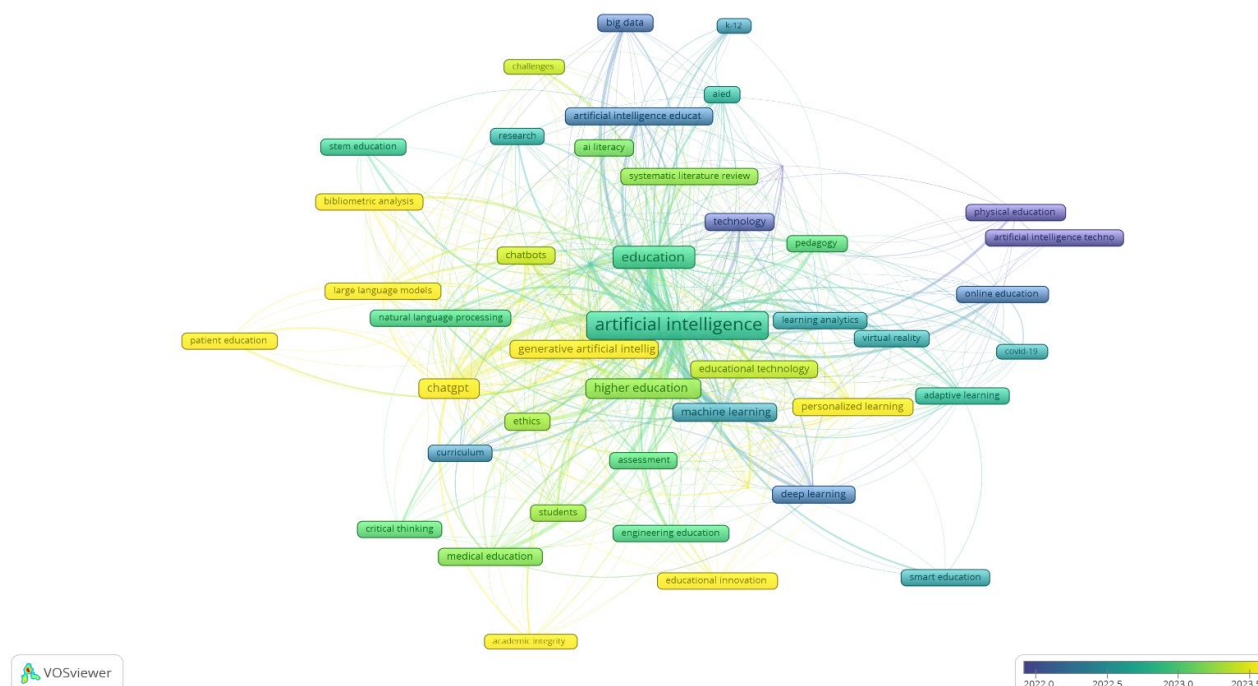


Figure 4 Evolution of AI in education and future trends from author keyword co-occurrences. *Source:* Scopus and WoS databases.

Looking ahead, AI in education is expected to progress in several key directions. Hyper-personalisation is likely to become a defining characteristic, as AI leverages big data to deliver highly individualised learning experiences. The influence of generative AI is expected to continue expanding, enabling creative, adaptive, and context-specific content delivery. Immersive technologies such as the metaverse are poised to enhance experiential learning further, while continued advances in AI ethics and governance frameworks will be essential to ensuring that these technologies are implemented in a responsible and equitable manner. The interconnectedness of the keywords in the network visualisation reflects the depth and complexity of AI's role in education. By addressing ethical challenges and promoting digital equity while embracing technological innovation, educators and policymakers can harness the potential of AI to create inclusive, transformative, and sustainable educational environments for the future.

4. Conclusion

The bibliometric analysis highlights the rapid growth and interdisciplinary nature of research at the intersection of artificial intelligence (AI) and education, particularly during the years 2022–2023. The findings underscore the dominance of education and educational research as a primary category, reflecting AI's transformative impact on pedagogy, curriculum development, and learning outcomes. Emerging keywords such as adaptive learning systems, generative AI, and immersive technologies like virtual reality showcase AI's potential to personalise education and enhance student engagement. Geographical analysis reveals that countries with robust governmental support, such as China, the United States, and India, are leading contributors, emphasising the role of national policies and research infrastructure in advancing AI-driven education. Moreover, the most highly cited publications explore adaptive learning, ethical considerations, and generative AI, underlining the significance of these areas in shaping educational innovation. The network visualisation further illustrates interconnected keywords, with “artificial intelligence” positioned at the centre, connected to diverse nodes like “personalised learning,” “AI literacy,” and “virtual reality.” This reflects the multidisciplinary impact of AI in education, ranging from cognitive psychology and environmental literacy to workforce readiness and equity in digital learning. However, challenges such as ethical concerns, data privacy, and equitable access remain critical barriers to widespread implementation.

The future of research on artificial intelligence (AI) in education offers exciting possibilities to expand its scope and impact. A critical area for future exploration is hyper-personalised learning. AI systems have the potential to deliver highly tailored educational experiences by analysing students' learning styles, preferences, and needs. This can significantly enhance student engagement and learning outcomes while addressing diverse learner requirements. Despite providing valuable insights, the study's focus on recent years (2022–2023), which is the novelty of this research, while offering a timely perspective, may inadvertently overlook foundational research and long-term trends in the application of AI to education.

Acknowledgment



We would like to express our sincere gratitude to University of Technology Sarawak and individuals who have contributed to the successful completion of this bibliometric study.

5. Declarations

5.1. Ethical considerations

Not applicable.

5.2. Use of artificial intelligence (AI)

The authors declare that no generative artificial intelligence (AI) tools were used in the preparation, analysis, or writing of this manuscript.

5.3. Conflict of interest

The authors declare no conflicts of interest.

5.4. Funding

This research is supported by University of Technology Sarawak, UTS/RESEARCH/1/2024/02.

References

- Afzaal, M. (2024). Mapping artificial intelligence integration in education: A decade of innovation and impact (2013–2023)—A bibliometric analysis. *IEEE Access*, 12, 113275–113299. <https://doi.org/10.1109/ACCESS.2024.3443313>
- Akhmadieva, R. (2023). Artificial intelligence in science education: A bibliometric review. *Contemporary Educational Technology*, 15(4), ep460. <https://doi.org/10.30935/cedtech/13587>
- Al-Maskari, A., Al Riyami, T., & Ghnimi, S. (2024). Factors affecting students' preparedness for the fourth industrial revolution in higher education institutions. *Journal of Applied Research in Higher Education*, 16(1), 246–264. <https://doi.org/10.1108/JARHE-05-2022-0169>
- Almusaed, A., Almssad, A., Yitmen, I., & Homod, R. Z. (2023). Enhancing student engagement: Harnessing AIED's power in hybrid education—A review analysis. *Education Sciences*, 13(7), 632. <https://doi.org/10.3390/educsci13070632>
- Atibuni, D. Z., Manyiraho, D., & Nabitula, A. N. (2022). A fourth industrial revolution paradigm shift in teacher education? *International Journal of African Higher Education*, 9(2), 1–21. <https://doi.org/10.6017/ijahe.v9i2.15365>
- Bahroun, Z., Anane, C., Ahmed, V., & Zacca, A. (2023). Transforming education: A comprehensive review of generative artificial intelligence in educational settings through bibliometric and content analysis. *Sustainability*, 15(17), 12983. <https://doi.org/10.3390/su151712983>
- Batubara, H. S., Jalinus, N., Rizal, F., & Watrianthos, R. (2024). Mapping the frontier: A bibliometric analysis of AI in tertiary education. *International Journal of Learning, Teaching and Educational Research*, 23(10), 62–81. <https://doi.org/10.26803/ijlter.23.10.4>
- Bolón-Canedo, V., Morán-Fernández, L., Cancela, B., & Alonso-Betanzos, A. (2024). A review of green artificial intelligence: Towards a more sustainable future. *Neurocomputing*, 128096. <https://doi.org/10.1016/j.neucom.2024.128096>
- Castro, R. (2024). Bibliometric review on teaching methods with artificial intelligence in education. *Online Journal of Communication and Media Technologies*, 14(2), e202419. <https://doi.org/10.30935/ojcm/14367>
- Chan, C. K. Y. (2023). A comprehensive AI policy education framework for university teaching and learning. *International Journal of Educational Technology in Higher Education*, 20(1), 38. <https://doi.org/10.1186/s41239-023-00408-3>
- Chassignol, M., Khoroshavin, A., Klimova, A., & Bilyatdinova, A. (2018). Artificial intelligence trends in education: A narrative overview. *Procedia Computer Science*, 136, 16–24. <https://doi.org/10.1016/j.procs.2018.08.233>
- Chen, L., Chen, P., & Lin, Z. (2020). Artificial intelligence in education: A review. *IEEE Access*, 8, 75264–75278. <https://doi.org/10.1109/ACCESS.2020.2988510>
- Ciaccio, F. (2024). The supporting role of artificial intelligence and machine/deep learning in monitoring the marine environment: A bibliometric analysis. *Ecological Questions*, 35(1), 1–30. <https://doi.org/10.12775/eq.2024.005>
- Cooper, G. (2023). Examining science education in ChatGPT: An exploratory study of generative artificial intelligence. *Journal of Science Education and Technology*, 32(3), 444–452. <https://doi.org/10.1007/s10956-023-10039-y>
- Demartini, C. G., Sciascia, L., Bosso, A., & Manuri, F. (2024). Artificial intelligence bringing improvements to adaptive learning in education: A case study. *Sustainability*, 16(3), 1347. <https://doi.org/10.3390/su16031347>
- Durak, G. (2024). Artificial intelligence in education: A bibliometric study on its role in transforming teaching and learning. *The International Review of Research in Open and Distributed Learning*, 25(3), 219–244. <https://doi.org/10.19173/irrodl.v25i3.7757>
- Eysenbach, G. (2023). The role of ChatGPT, generative language models, and artificial intelligence in medical education: A conversation with ChatGPT and a call for papers. *JMIR Medical Education*, 9(1), e46885. <https://doi.org/10.2196/46885>
- Habila, M. A., Ouladsmame, M., & Alothman, Z. A. (2023). Role of artificial intelligence in environmental sustainability. In *Visualization techniques for climate change with machine learning and artificial intelligence* (pp. 449–469). Elsevier. <https://doi.org/10.1016/B978-0-323-99714-0.00009-1>
- Hinojo-Lucena, F., Díaz, I., Reche, M., & Rodríguez, J. (2019). Artificial intelligence in higher education: A bibliometric study on its impact in the scientific literature. *Education Sciences*, 9(1), 51. <https://doi.org/10.3390/educsci9010051>
- Huang, A. Y., Lu, O. H., & Yang, S. J. (2023). Effects of artificial intelligence-enabled personalized recommendations on learners' learning engagement, motivation, and outcomes in a flipped classroom. *Computers & Education*, 194, 104684. <https://doi.org/10.1016/j.compedu.2022.104684>
- Husaeni, D. (2022). Chatbot artificial intelligence as educational tools in science and engineering education: A literature review and bibliometric mapping analysis with its advantages and disadvantages. *ASEAN Journal of Science and Engineering*, 4(1), 93–118. <https://doi.org/10.17509/ajse.v4i1.67429>

- Hwang, G. J., & Chien, S. Y. (2022). Definition, roles, and potential research issues of the metaverse in education: An artificial intelligence perspective. *Computers and Education: Artificial Intelligence*, 3, Article 100082. <https://doi.org/10.1016/j.caeai.2022.100082>
- Järvelä, S., Nguyen, A., & Hadwin, A. (2023). Human and artificial intelligence collaboration for socially shared regulation in learning. *British Journal of Educational Technology*, 54(5), 1057–1076. <https://doi.org/10.1111/bjet.13325>
- Johri, A., Katz, A. S., Qadir, J., & Hingle, A. (2023). Generative artificial intelligence and engineering education. *Journal of Engineering Education*, 112(3). <https://doi.org/10.1002/jee.20537>
- Kaushik, R., Parmar, M., & Jhamb, S. (2021). Roles and research trends of artificial intelligence in mathematics education. In *Proceedings of the 2021 International Conference on Mathematics and Science Teaching (ICCMST)* (pp. 202–205). <https://doi.org/10.1109/ICCMST54943.2021.00050>
- Kavitha, K. (2024). Artificial intelligence in higher education: A bibliometric approach. *European Journal of Educational Research*, 13(3), 1121–1137. <https://doi.org/10.12973/eu-jer.13.3.1121>
- Khanal, S., Zhang, H., & Taeihagh, A. (2024). Development of new generation of artificial intelligence in China: When Beijing's global ambitions meet local realities. *Journal of Contemporary China*, 1–24. <https://doi.org/10.1080/10670564.2024.2333492>
- Khlaif, Z. N., Ayyoub, A., Hamamra, B., Bensalem, E., Mitwally, M. A., Ayyoub, A., ... Shadid, F. (2024). University teachers' views on the adoption and integration of generative AI tools for student assessment in higher education. *Education Sciences*, 14(10), 1090. <https://doi.org/10.3390/educsci14101090>
- Lim, W. M., Gunasekara, A., Pallant, J. L., Pallant, J. I., & Pechenkina, E. (2023). Generative AI and the future of education: Ragnarök or reformation? A paradoxical perspective from management educators. *The International Journal of Management Education*, 21(2), 100790. <https://doi.org/10.1016/j.ijme.2023.100790>
- Lin, H., & Chen, Q. (2024). Artificial intelligence (AI)-integrated educational applications and college students' creativity and academic emotions. *BMC Psychology*, 12, 487. <https://doi.org/10.1186/s40359-024-01979-0>
- Liu, D. Y. T., Bartimote-Aufflick, K., Pardo, A., & Bridgeman, A. J. (2017). Data-driven personalization of student learning support in higher education. In *Learning analytics: Fundamentals, applications, and trends* (pp. 143–169). Springer. https://doi.org/10.1007/978-3-319-52977-6_5
- Liu, M., Ren, Y., Nyagoga, L. M., Stonier, F., Wu, Z., & Yu, L. (2023). Future of education in the era of generative artificial intelligence: Consensus among Chinese scholars on applications of ChatGPT in schools. *Future in Educational Research*, 1(1), 72–101. <https://doi.org/10.1002/fer3.10>
- Lubis, A. (2024). A bibliometric mapping analysis of publications on the utilization of artificial intelligence technology in language learning. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, 38(1), 156–176. <https://doi.org/10.37934/araset.38.1.156176>
- Lutfiani, N., Wijono, S., Rahardja, U., Iriani, A., Aini, Q., & Septian, R. A. D. (2022). A bibliometric study: Recommendation based on artificial intelligence for iLearning education. *Aptisi Transactions on Technopreneurship*, 5(2), 109–117. <https://doi.org/10.34306/att.v5i2.279>
- Mohamad, A. H. H., & Ab-Rahim, R. (2025). Mapping the research landscape of energy market and renewable energy: A bibliometric analysis. *International Journal of Renewable Energy Development*, 14(4), 703–716. <https://doi.org/10.61435/ijred.2025.61058>
- Mohamad, A. H. H., Ab-Rahim, R., Kushairi, A. R. E., & Esa, M. S. M. (2024a). Housing market: A bibliometric analysis from 2020 to 2024. *International Journal of Academic Research in Business and Social Sciences*, 14(8), 274–295. <https://doi.org/10.6007/IJARBS/v14-i8/22390>
- Mohamad, A. H. H., Rosli, S. N. F. A., Ab-Rahim, R., Rashid, N. K. A., & Esa, M. S. M. (2024b). Poverty in Malaysia region: A bibliometric analysis. *International Journal of Academic Research in Business and Social Sciences*, 14(8), 1676–1700. <https://doi.org/10.6007/IJARBS/v14-i8/22537>
- Mong, D. (2024). Relationship between artificial intelligence and legal education: A bibliometric analysis. *Knowledge and Performance Management*, 8(2), 13–27. [https://doi.org/10.21511/kpm.08\(2\).2024.02](https://doi.org/10.21511/kpm.08(2).2024.02)
- Montalván, B. (2024). The influence of artificial intelligence in higher education based on four thematic axes: A bibliometric study. *Sapienza International Journal of Interdisciplinary Studies*, 5(2), e24035. <https://doi.org/10.51798/sijis.v5i2.764>
- Nedungadi, P., Tang, K. Y., & Raman, R. (2024). The transformative power of generative artificial intelligence for achieving the sustainable development goal of quality education. *Sustainability*, 16(22), 9779. <https://doi.org/10.3390/su16229779>
- Pantelimon, F. V., Bologa, R., Toma, A., & Posedaru, B. S. (2021). The evolution of AI-driven educational systems during the COVID-19 pandemic. *Sustainability*, 13(23), 13501. <https://doi.org/10.3390/su132313501>
- Peters, M. A., & Green, B. J. (2024). Wisdom in the age of AI education. *Postdigital Science and Education*, 1–23. <https://doi.org/10.1007/s42438-024-00460-w>
- Popenici, S. A., & Kerr, S. (2017). Exploring the impact of artificial intelligence on teaching and learning in higher education. *Research and Practice in Technology Enhanced Learning*, 12(1), 22. <https://doi.org/10.1186/s41039-017-0062-8>
- Prahani, B., Rizki, I., Jatmiko, B., Suprpto, N., & Tan, A. (2022). Artificial intelligence in education research during the last ten years: A review and bibliometric study. *International Journal of Emerging Technologies in Learning*, 17(8), 169–188. <https://doi.org/10.3991/ijet.v17i08.29833>
- Preiksaitis, C., & Rose, C. (2023). Opportunities, challenges, and future directions of generative artificial intelligence in medical education: Scoping review. *JMIR Medical Education*, 9, e48785. <https://doi.org/10.2196/48785>
- Rahman, A. (2024). A comprehensive bibliometric and content analysis of artificial intelligence in language learning. *Artificial Intelligence Review*, 57(4). <https://doi.org/10.1007/s10462-023-10643-9>
- Roll, I., & Wylie, R. (2016). Evolution and revolution in artificial intelligence in education. *International Journal of Artificial Intelligence in Education*, 26, 582–599. <https://doi.org/10.1007/s40593-016-0110-3>
- Salinas-Navarro, D. E., Vilalta-Perdomo, E., Michel-Villarreal, R., & Montesinos, L. (2024). Using generative artificial intelligence tools to explain and enhance experiential learning for authentic assessment. *Education Sciences*, 14(1), 83. <https://doi.org/10.3390/educsci14010083>
- Singaram, S., Mayer, C. H., & Oosthuizen, R. M. (2023). Leading higher education into the fourth industrial revolution: An empirical investigation. *Frontiers in Psychology*, 14, 1242835. <https://doi.org/10.3389/fpsyg.2023.1242835>
- Song, P., & Wang, X. (2020). A bibliometric analysis of worldwide educational artificial intelligence research development in recent twenty years. *Asia Pacific Education Review*, 21(3), 473–486. <https://doi.org/10.1007/s12564-020-09640-2>
- Strielkowski, W., Grebennikova, V., Lisovskiy, A., Rakhimova, G., & Vasileva, T. (2024). AI-driven adaptive learning for sustainable educational transformation. *Sustainable Development*, 1–27. <https://doi.org/10.1002/sd.3221>



- Ullrich, A., Vladova, G., Eigelshoven, F., & Renz, A. (2022). Data mining of scientific research on artificial intelligence in teaching and administration in higher education institutions. *Discover Artificial Intelligence*, 2(1). <https://doi.org/10.1007/s44163-022-00031-7>
- Verma, N., Getenet, S., Dann, C., & Shaik, T. (2023). Designing an artificial intelligence tool to understand student engagement. *Computers and Education: Artificial Intelligence*, 5, 100187. <https://doi.org/10.1016/j.caeai.2023.100187>
- Wang, S., Yang, L., Li, M., Zhang, X., & Tai, X. (2024). Medical education and artificial intelligence: Web of Science–based bibliometric analysis (2013–2022). *JMIR Medical Education*, 10(1), e51411. <https://doi.org/10.2196/51411>
- Wu, F., Lu, C., Zhu, M., Chen, H., Zhu, J., Yu, K., ... Pan, Y. (2020). Towards a new generation of artificial intelligence in China. *Nature Machine Intelligence*, 2(6), 312–316. <https://doi.org/10.1038/s42256-020-0183-4>
- Wu, T. (2024). Bibliometric and systematic analysis of artificial intelligence chatbots' use for language education. *Journal of University Teaching and Learning Practice*, 21(6). <https://doi.org/10.53761/6jmnst54>
- Xie, X., Siau, K., & Nah, F. F. H. (2020). COVID-19 pandemic—online education in the new normal and the next normal. *Journal of Information Technology Case and Application Research*, 22(3), 175–187. <https://doi.org/10.1080/15228053.2020.1824884>
- Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education. *International Journal of Educational Technology in Higher Education*, 16(1), 1–27. <https://doi.org/10.1186/s41239-019-0171-0>