

Trends and emerging themes in the effects of generative artificial intelligence in education: A systematic review

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Abstract

This paper systematically reviews the impact of Generative Artificial Intelligence (GenAI) in education from 2021 to 2024. The objective is to explore key trends, geographical distribution of research, and emerging themes in the educational use of GenAI, while addressing ethical challenges such as algorithmic bias, data privacy, and the digital divide. Using a systematic review methodology guided by four research questions, the study analyzes publications in Scopus to identify dominant research themes and leading countries in the field. Results indicate that the United States, the United Kingdom, and Singapore are the top contributors to GenAI research, with a primary focus on personalized learning and automated assessments. The review highlights a surge in publications, particularly in 2023, driven by advancements in AI tools like ChatGPT. It emphasizes the importance of international collaboration and proposes the need for regulatory frameworks to ensure the ethical integration of AI in education. This review offers valuable insights into the current state of GenAI research in education and provides recommendations for educators, policymakers, and researchers to navigate the challenges and opportunities of AI-driven learning.

Keywords: generative artificial intelligence (GenAI), PRISMA, personalized learning, algorithmic bias, ethical concerns, international collaboration, systematic review

INTRODUCTION

The rapid development of Generative Artificial Intelligence (GenAI) in recent years has positioned it as a transformative force in education, offering unprecedented capabilities in personalizing learning experiences, automating content creation, and enhancing student engagement. Unlike traditional AI systems, which are often designed for specific, rule-based tasks, GenAI leverages advanced machine learning algorithms to generate new and unique content, such as tailored educational materials, interactive simulations, and even personalized assessments. These innovations hold the potential to address diverse learner needs more effectively than ever before, making education more adaptive and student-centered (Ismail et al., 2023; Moorhouse & Kohnke, 2024).

Generative Artificial Intelligence (GenAI) tools, such as ChatGPT, are revolutionizing mathematics education by enhancing student engagement and learning

outcomes. Recent studies highlight ChatGPT's versatility, with Gouia-Zarrad and Gunn (2024) demonstrating its effectiveness in fostering active learning and coding skills in a differential equations course, and Korkmaz Guler et al. (2024) showcasing its ability to solve statistical problems in national exams. However, limitations remain in addressing advanced topics like algebra and calculus, emphasizing the need for continued development. Beyond higher education, GenAI shows promise in early childhood and interdisciplinary contexts. Samara and Kotsis (2024) documented its success in teaching magnetism to preschoolers, while Su (2024) demonstrated the value of integrating AI tools into problem-based learning to foster collaboration and self-directed learning. These findings underline the transformative potential of GenAI across diverse educational settings. The adoption and perception of GenAI differ significantly across educational contexts and demographics. For instance, Saudi students value AI for enhancing learning

Contribution to the literature

- This article has reviewed the current state of Generative AI (GenAI) research in education from 2021 to 2024.
- This research has identified leading countries, key contributors, and major publications shaping the discourse on GenAI in education.
- This study has highlighted three main research directions: the role of GenAI in personalized learning, its application in automated assessments, and the ethical challenges associated with AI integration in education.

outcomes while raising concerns about academic integrity (Aldossary et al., 2024). Similarly, gifted students recognize AI's benefits but approach its risks with caution (Görgülü & Törün, 2025).

However, as the integration of GenAI into educational practices accelerates, it also raises critical challenges that must be addressed. Ethical concerns, particularly those related to algorithmic bias and data privacy, have emerged as significant issues in the discourse on AI in education. For instance, if the data used to train these AI systems is biased, the resulting outputs may perpetuate or even exacerbate inequalities, leading to unfair treatment of certain student groups (Dimitriadou et al, 2023). Additionally, the increasing reliance on AI-driven tools in education risks widening the digital divide, as access to these advanced technologies often depends on the resources available to educational institutions, potentially leaving underfunded schools and students at a disadvantage (Garlinska et al., 2023).

Given the transformative potential and accompanying challenges of GenAI, a systematic review of the existing literature is both timely and necessary. This review aims to identify key trends in the application of GenAI in education from 2021 to 2024, a period marked by significant advancements in AI technology and its growing adoption in educational settings. By analyzing the geographical distribution of research activities, this study will also highlight the contributions of various countries to the development of AI in education and explore patterns of international collaboration. Furthermore, the review will identify the most influential journals in this field, providing insight into the academic platforms that are driving the discourse on GenAI. Finally, by synthesizing emerging themes from recent studies, this review will offer a comprehensive overview of the current state of research on GenAI in education, identifying both the opportunities and challenges that lie ahead (Ali et al., 2021; Moorhouse & Kohnke, 2024).

This systematic review is structured around four key research questions:

- RQ1** What is the trend of research papers on the application of Generative AI in education from 2021 to 2024, and how has the number of publications changed over the years?

- RQ2** Which countries are most active in researching Generative AI in education, and what are the patterns of collaboration between these countries?

- RQ3** Which journals are the most influential in the field of Generative AI in education?

- RQ4** What emerging themes and trends can be synthesized from recent research on Generative AI in education?

Addressing these questions will not only map the current landscape of GenAI research in education but also provide valuable insights for educators, policymakers, and researchers looking to harness the full potential of AI in educational contexts.

LITERATURE REVIEW

Overview of Generative AI in Education

Generative AI (GenAI) represents a significant technological advancement, defined as a subset of artificial intelligence capable of creating new content such as text, images, or even more complex forms based on input data. In education, GenAI has found applications in various areas, including personalized learning, content generation, and real-time feedback systems, offering educators new ways to engage learners and improve educational outcomes (Ali et al., 2021; Chiu, 2024). Historically, artificial intelligence in education has been focused on adaptive learning systems and learning analytics, which primarily facilitated the monitoring of student progress and performance (Ismail et al., 2023). However, since the advent of GenAI, the application scope has expanded, offering more dynamic learning environments that respond to individual student needs (Moorhouse & Kohnke, 2024).

Previous Studies on AI Trends in Education

Prior research has examined how AI has transformed educational processes, especially concerning personalized learning and automated assessment tools. Studies by Nguyen and Nguyen (2023) and Dimitriadou et al. (2023) explored AI's capacity to provide real-time assessments and feedback, demonstrating a marked improvement in student engagement. Although these

studies laid foundational work on AI's educational applications, gaps remain in the literature, particularly concerning the long-term impact of GenAI on learning outcomes and the ethical considerations tied to its use (Garlinska et al., 2023). This systematic review seeks to fill these gaps by focusing specifically on GenAI's trends from 2021 to 2024, addressing the emerging themes and challenges highlighted in recent studies.

Importance of Geographical Analysis and Collaboration in AI Research

Geographical analysis and international collaboration have become increasingly important in the field of AI research in education. According to recent studies, China, the United States, and the United Arab Emirates are leading contributors to research on AI in education (Alneyadi & Wardat, 2024). Collaboration between these countries has accelerated the development of AI technologies and facilitated the sharing of best practices across different educational systems (Salloum et al., 2023). Research by Lo (2023) emphasized the significance of cross-border partnerships in improving the efficiency and reach of GenAI in education, particularly in developing countries. This review includes a focus on the geographical distribution of AI research and the impact of international collaboration, which is vital for the global dissemination and improvement of educational technologies.

Influence of Academic Journals in Educational AI Research

The role of academic journals in advancing AI research cannot be overstated. Journals such as *Computers & Education* and *Journal of Applied Learning and Teaching* have played a pivotal role in publishing studies that explore the integration of AI in education (Moorhouse & Kohnke, 2024). These publications are instrumental in shaping current trends, with many focusing on AI applications in adaptive learning, content creation, and automated teaching tools (Rangel-de Lázaro & Duarte, 2023). Citation analysis reveals that studies published in high-impact journals often set the agenda for further research in the field, driving innovation and fostering an interdisciplinary approach to AI in education (Nguyen & Nguyen, 2023).

Emerging Themes in Educational AI

Several emerging themes have been identified in recent studies on the application of GenAI in education. Personalized learning, where AI adapts content to meet individual student needs, remains a dominant focus (Ali et al., 2021). Additionally, the ethical implications of AI, particularly concerning data privacy and algorithmic bias, are becoming central to the discourse (Dimitriadou et al., 2023). Moreover, research has increasingly focused

on AI-driven instructional support tools that assist educators in enhancing teaching effectiveness and student engagement (Moorhouse & Kohnke, 2024). These emerging themes reflect the dynamic nature of GenAI's integration into education and highlight areas that require further exploration, particularly in terms of ethical AI usage and equitable access to AI-driven learning tools (Nguyen & Nguyen, 2023).

MATERIALS AND METHODS

Research Design

This study employs a systematic review approach to identify, evaluate, and synthesize the existing body of literature on teachers' preparation for teaching in the digital environment. The systematic review methodology allows for a structured and comprehensive analysis of relevant studies, ensuring that the findings are both rigorous and reproducible. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines were followed to enhance transparency and minimize the risk of bias throughout the review process.

Data Sources and Search Strategy

In this study, Scopus was selected as the primary database to retrieve relevant literature on the effects of Generative AI in education. The data selection process follows the PRISMA methodology, ensuring a rigorous and systematic approach to identifying, screening, and including studies. To ensure comprehensive coverage of the literature, we developed a search strategy using a combination of keywords, Boolean operators, and controlled vocabulary. The search phrase used in this review was: *TITLE-ABS-KEY ("the AND effects AND of AND generative AND AI AND in AND education")*.

Data Extraction and Analysis

Data from the selected studies were extracted systematically, focusing on key themes such as the methods used in teacher preparation, the challenges and opportunities associated with teaching in digital environments, and the effectiveness of different training programs. The extracted data were then analyzed to identify trends, common findings, and gaps in the literature. **Bibliometric analysis tools such as VOSviewer were employed to visualize keyword co-occurrence, collaboration networks, and the geographical distribution of research.** This analysis helped to provide a comprehensive overview of the current state of research on teachers' preparation for teaching in digital environments, highlighting areas for future investigation.

The PRISMA diagram (Figure 1) illustrates the systematic review process, starting with the identification of 131 records from databases. After

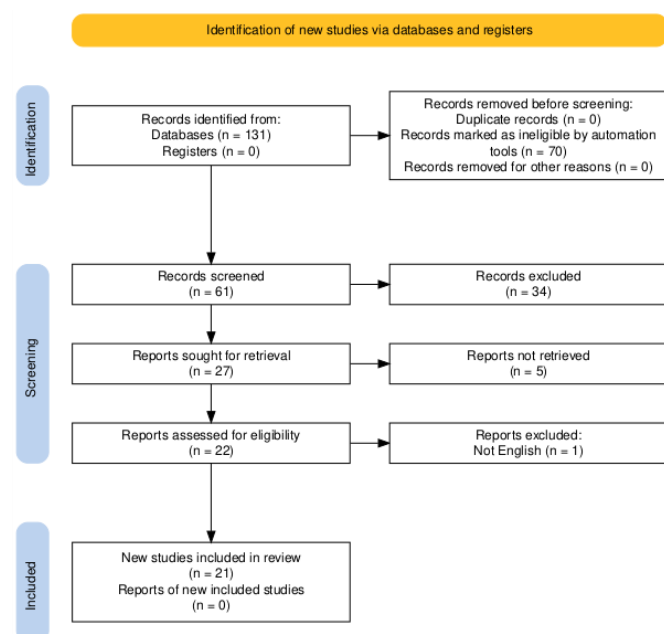


Figure 1. PRISMA flow diagram (Source: Data selected from Scopus [<https://www.scopus.com/>] on August 15th 2024)

removing duplicates and ineligible entries, 61 records proceeded to the screening stage. Of these, 34 were excluded based on title and abstract evaluation, leaving 27 reports for retrieval. However, 5 reports could not be retrieved, and 22 were assessed for eligibility. Ultimately, 1 report was excluded due to language constraints, resulting in 21 studies being included in the final review. This process highlights the rigorous filtering applied to ensure the relevance and quality of the studies selected for the systematic review.

RESULTS

Research Question RQ1: What is the Trend of Research Papers on the Application of Generative AI in Education From 2021 to 2024, and How Has the Number of Publications Changed Over the Years?

The publication trend on Generative AI in education has exhibited a sharp increase between 2021 and 2024, reflecting the growing scholarly interest in the field. Based on the bibliometric data presented in **Figure 2**, the number of relevant research articles increased from 1 publication in 2021 to 9 in 2023, before reaching its peak at 11 publications in 2024. This trajectory suggests a significant acceleration in research output, particularly post-2022.

The notable increase from 2022 onwards can be attributed to advancements in AI technologies, particularly the widespread adoption of OpenAI's ChatGPT and similar models, which have facilitated new educational applications. The lack of research activity in 2022 followed by a surge in 2023 and 2024 suggests that the field was initially in an exploratory

phase, but with rapid adoption and integration into educational frameworks, scholarly engagement intensified.

This trend aligns with the broader movement towards AI-enhanced personalized learning, assessment, and content generation in education. As research continues to expand, future studies are expected to explore longitudinal effects of AI-driven education, ethical concerns, and the efficacy of adaptive AI tutoring systems.

From the dataset, it's clear that research on the application of Generative AI in education has significantly grown between 2021 and 2023. Early works like Ali et al. (2021) explored the theoretical aspects and potential roles of AI in shaping education, particularly for children as creators and critical thinkers. By 2023, the number of publications surged, particularly driven by the advancements in AI tools such as OpenAI's ChatGPT, which became a pivotal subject for educational applications.

For example, Hassoulas et al. (2023) investigated the use of AI in distinguishing between student-written content and AI-generated content like ChatGPT, reflecting the growing concern and interest in the practical applications of Generative AI. The introduction of more advanced tools has led to a greater focus on AI's integration in the educational system, as shown by Ismail et al. (2023), where AI is applied to assessments in higher education.

The keyword "ChatGPT" became prevalent in the 2023 studies, showing a clear shift from theoretical exploration to practical deployment in educational settings. This trend is expected to continue, with future research anticipated to explore broader implications for teaching, learning, and assessment (Bower et al., 2024).

The demand for AI literacy in education has significantly increased, particularly in elementary and STEAM (Science, Technology, Engineering, Arts, and Mathematics) education. Relmasira et al. (2023) highlight the growing need to introduce AI concepts at an early stage, ensuring that students not only use AI tools but also understand their underlying principles. This trend aligns with the increasing number of publications focusing on AI integration in K-12 education. AI-powered game-based learning is emerging as a key pedagogical approach, enhancing cognitive flexibility and domain-specific problem-solving. Research on AI-driven personalized and adaptive learning has increased significantly, with studies like Pesovski et al. (2024) demonstrating AI's role in automating instructional material generation and enhancing student engagement. Sian et al. (2024) demonstrate that AI-driven gamification can be customized to meet different educational needs, fostering both analytical and creative skill development.

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21 document results

Select year range to analyze: 2021 to 2024 Analyze

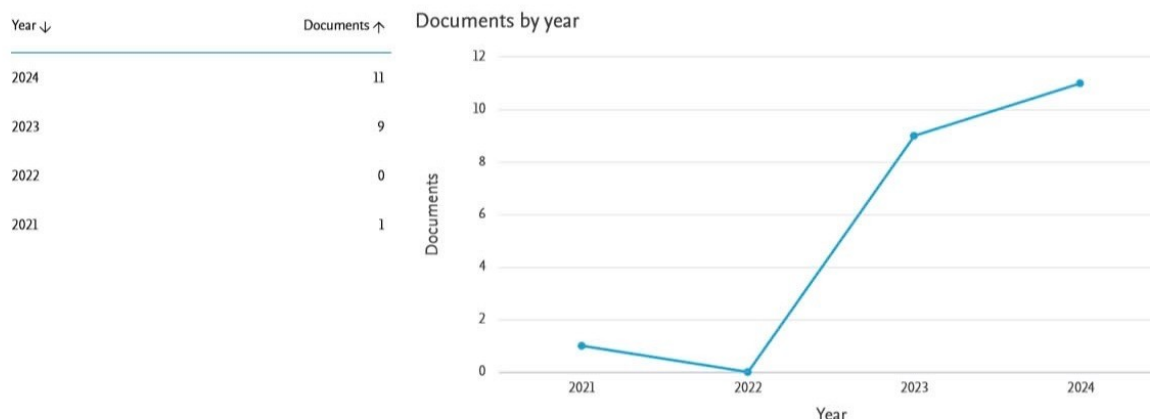


Figure 2. Publications on AI in education (Source: Data selected from Scopus [<https://www.scopus.com/>] on August 15th 2024)

Research Question RQ2: Which Countries Are Most Active in researching Generative AI in education, and what are the patterns of collaboration between these countries?

Based on the affiliations from the dataset, the most active countries in researching Generative AI in education include the United States, United Kingdom, and Singapore. For instance, Ali et al. (2021), affiliated with the Massachusetts Institute of Technology (MIT), contributed significantly to research on digital literacy and generative AI, reflecting the U.S.'s leading role in this domain.

Similarly, the UK is well-represented, with studies like Hassoulas et al. (2023) from Cardiff University examining the implications of AI in education, specifically its role in assessments. Singapore also plays a key role, with researchers such as Ismail et al. (2023) from Kaplan Singapore focusing on AI-driven assessment methods in higher education. The patterns of collaboration between these countries are evident, as many studies feature international co-authorship, particularly between Western and Asian institutions. For example, the collaboration between researchers in Hong Kong (Moorhouse & Kohnke, 2024) and other international partners reflects the global nature of AI research. This growing international collaboration is essential for addressing ethical, pedagogical, and practical concerns across different educational systems.

While the US and UK dominate AI research in education, European institutions, including those in North Macedonia and Portugal, are actively exploring AI-enhanced pedagogical strategies and LMS implementations (Pesovski et al., 2024). Turkey has made notable contributions to AI-enhanced programming instruction (Yilmaz & Karaoglan Yilmaz,

2023). Their study on AI-driven programming environments at Bartın University demonstrates how AI supports computational skill development in higher education.

Singapore has established itself as a leading hub for AI-driven research on knowledge discourse, with a growing body of studies examining AI's role in facilitating and sustaining collaborative student interactions. Lee et al. (2023) investigate how AI-powered learning environments at Nanyang Technological University enhance student agency in knowledge construction, further reinforcing Singapore's position at the forefront of AI-integrated smart classroom development. Sian et al. (2024) highlight how AI-driven learning models in Malaysian universities support interdisciplinary innovation in education.

Research Question RQ3: Which Journals Are the Most Influential in the Field of Generative AI in Education?

The dataset highlights several influential journals that are frequently publishing research on Generative AI in education. Notable journals include *Computers and Education: Artificial Intelligence*, which published studies like Ali et al. (2021), focusing on AI's educational applications, particularly in helping students become creators and thinkers. This journal is well regarded for exploring the intersection of AI and educational technologies. *Education and Information Technologies*, where Bower et al. (2024) discussed the impact of AI tools like ChatGPT on teaching and assessment. This journal is becoming increasingly influential as more research focuses on the digital transformation of education. *Journal of Applied Learning and Teaching*, which has seen several impactful articles, such as

Hassoulas et al. (2023) and Ismail et al. (2023), that explore practical applications of AI in educational contexts, particularly around assessment and the role of AI in higher education. These journals are central to advancing the discourse around AI's role in education, with many articles drawing significant citations and sparking ongoing debates about the future of education in the digital age.

Interdisciplinary journals like Sustainability have published key studies on AI-driven education, including Pesovski et al. (2024), which examines AI-generated customizable learning experiences and their impact on digital pedagogy.

The Journal of Applied Learning & Teaching has emerged as a significant venue for research on Generative AI's role in online and distance education. Sevnanarayan and Potter (2024) contribute to this discourse by examining the transformative effects of ChatGPT in South African higher education institutions, emphasizing the importance of balancing AI-enhanced learning with institutional policies on academic integrity.

The Computers and Education: Artificial Intelligence journal has been instrumental in publishing research on AI's role in programming education (Yilmaz & Karaoglan Yilmaz, 2023). Their work highlights AI's potential to boost student motivation and learning effectiveness in coding courses.

Smart Learning Environments has become an influential journal in the field of AI-supported student discourse. Lee et al. (2023) contribute to this growing body of research by examining AI's ability to facilitate student-centered discussions, knowledge building, and ideation in smart classrooms.

Zheltukhina et al. (2024) highlight that open-access journals such as JMIR Medical Education and Education Sciences are among the most cited, facilitating broader dissemination of AI research findings.

Journals such as Sustainability have become central to the discourse on AI literacy and its role in early education. Relmasira et al. (2023) emphasize the importance of interdisciplinary research in AI education, particularly studies that explore pedagogical frameworks and hands-on AI learning experiences for young students.

The Malaysian Journal of Learning and Instruction plays a pivotal role in advancing research on AI-driven gamification. Sian et al. (2024) provide empirical evidence on the impact of AI-enhanced simulations in fostering product innovation and cognitive engagement.

Research Question RQ4: What Emerging Themes and Trends Can Be Synthesized from Recent Research on Generative AI in Education?

Several emerging themes and trends are evident from recent research.

AI-assisted assessment and feedback

Studies like Ismail et al. (2023) show that AI tools are increasingly being used to automate assessment and provide real-time feedback to students. This trend is particularly prominent in higher education, where AI's role in assessments has been explored to ensure fairness, accuracy, and efficiency. Keywords like "assessment," "AI," and "feedback" frequently appear in research, indicating a growing focus on how AI can enhance both formative and summative evaluations (Figure 2).

Relmasira et al. (2023) propose a design-based research approach for AI literacy interventions, demonstrating how constructivist and transformative learning theories can be applied to AI education. Their study supports the notion that AI literacy should be embedded in STEAM education, ensuring that students develop critical thinking skills alongside technical competencies.

Generative AI for content creation

Another key trend is the use of Generative AI to create educational content, such as quizzes, exercises, and even study materials. Ali et al. (2021) discuss how students can use AI to develop their own projects, promoting creativity and critical thinking. This reflects a broader shift towards viewing students not just as consumers of content but also as co-creators in the learning process. Karakose et al. (2023) emphasize that AI-powered tools such as ChatGPT can enhance knowledge-building practices by providing real-time feedback, synthesizing new ideas, and ensuring that student discussions remain dynamic and productive. A key trend in AI education research is the adaptation of AI-powered learning environments for diverse academic disciplines. Sian et al. (2024) emphasize how AI-driven Digital Game-Based Learning enhances student engagement, problem-solving, and interdisciplinary collaboration, reinforcing the role of experiential learning.

Impact of ChatGPT and similar models on language learning

Moorhouse and Kohnke (2024) highlight how Generative AI models like ChatGPT are being used in language learning. The ability of these tools to provide real-time language practice and corrections is becoming an asset in language education, especially in the early stages of language acquisition. This trend is likely to

continue as AI tools become more sophisticated and tailored to specific learning contexts.

Ethical concerns and AI governance

Ethical concerns surrounding AI in education are a recurring theme in recent studies. Bower et al. (2024) emphasizes the importance of addressing issues like bias, data privacy, and over-reliance on AI tools in classrooms. These concerns are critical as AI becomes more integrated into educational systems, requiring well-defined frameworks to ensure that AI is used ethically and effectively.

While GenAI offers significant potential in facilitating interactive and knowledge-rich discussions, challenges persist regarding AI-generated misinformation, academic integrity, and student over-reliance on AI-assisted outputs. Lee et al. (2023) underscore the necessity of structured AI governance frameworks to ensure that AI serves as an augmentative tool that enhances, rather than supplants, student-driven learning and critical engagement. Zheltukhina et al. (2024) emphasize the need for institutional policies regulating AI use in academic settings to mitigate risks and ensure ethical AI integration. Relmasira et al. (2023) highlight the need for AI literacy programs that teach ethical AI usage, ensuring that students are aware of potential biases and privacy risks associated with AI technologies.

Creativity and student agency

Finally, a trend toward using AI to enhance creativity and student agency is emerging. Ali et al. (2021) explores how students can leverage AI to design innovative projects, suggesting that AI tools are shifting the

educational paradigm by enabling more creative, student-driven learning experiences.

GenAI is increasingly integrated into educational settings as a cognitive scaffold, facilitating structured discourse and iterative knowledge construction. Lee et al. (2023) highlight AI's capacity to identify salient discussion points, synthesize diverse perspectives, and refine conceptual understanding, thereby establishing a sustainable framework for student-driven inquiry and collaborative knowledge building.

DISCUSSION

GenAI has the potential to revolutionize education by offering personalized, adaptive learning experiences. However, to fully harness its benefits, it is critical to address the ethical, social, and technical challenges that accompany its integration into educational systems. International collaboration, clear regulatory policies, and a focus on equitable access will be key to ensuring that AI's role in education is both transformative and inclusive.

This section delves into the key findings of the study, drawing connections to the broader context of research in Generative AI (GenAI) in education, highlighting emerging trends, opportunities, and challenges based on data from 2021 to 2024.

Significant Growth in Research on Generative AI in Education

The findings clearly indicate a substantial growth in the number of research publications on the application of GenAI in education, especially between 2021 and 2024 (Figure 3). This surge is linked to the practical adoption of tools like ChatGPT in 2023 (Bower et al., 2024). Not

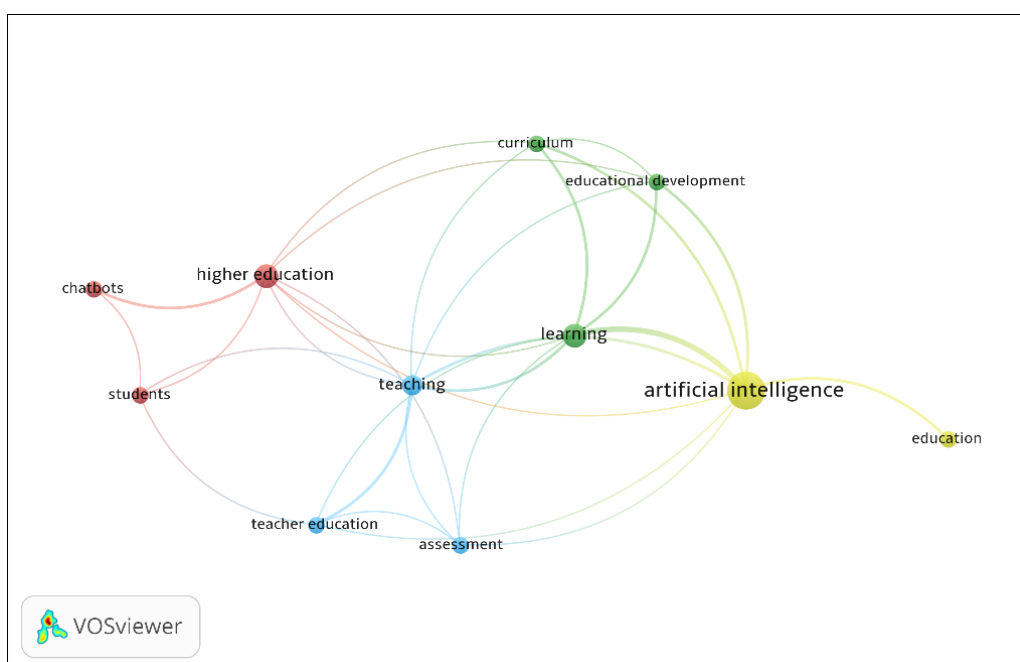


Figure 3. Keyword co-occurrence network analysis (Source: Authors' own elaboration, using VOSviewer)

only has the quantity of research increased, but the scope of AI applications has also expanded, from personalized learning content generation to automated student assessments (Ismail et al., 2023). This aligns with previous studies, which have indicated that GenAI is being adopted at an unprecedented rate in education (Ali et al., 2021). GenAI chatbots are increasingly being adopted in higher education for student support, personalized learning, and administrative automation, with Saihi et al. (2024) demonstrating that user trust, privacy concerns, and perceived usefulness significantly influence adoption rates.

AI-assisted learning, Pitso (2023) argues that asynchronous AI-enhanced education fosters greater student autonomy and engagement. The study highlights ChatGPT's role in accelerating assignment completion and improving students' problem-solving capabilities, demonstrating the growing reliance on AI for academic tasks.

Geographical Differences and International Collaboration

Our findings revealed that countries such as the United States, the United Kingdom, and Singapore are at the forefront of research on GenAI in education. This is largely due to their strong technical and financial resources, as well as the high level of academic engagement in these regions (Ali et al., 2021). International collaboration, especially between Western and Asian countries, has played a crucial role in accelerating the development of GenAI technologies and sharing best practices across educational systems (Salloum et al., 2023). These cross-border partnerships are essential for addressing the ethical, pedagogical, and practical challenges of AI in education.

Emerging Trends in the Application of Generative AI

Several key trends in the application of GenAI in education were identified.

Personalized content creation

AI is not only assisting educators but also enabling students to become creators of personalized learning materials tailored to individual needs (Ali et al., 2021; Divito et al., 2024). This shift towards personalized learning reflects the potential of GenAI to enhance the student learning experience through adaptive technologies. Karakose et al. (2023) emphasize that ChatGPT-4 demonstrated an improved ability to customize educational responses based on contextual prompts, making it a valuable tool for adaptive learning environments. AI-TPACK, a model that interconnects technological, pedagogical, and content knowledge, has gained traction as educators increasingly seek to integrate AI tools like ChatGPT into classroom instruction (Ning et al., 2024). GenAI is transforming

student discourse by enabling sustained knowledge creation and collaborative learning. Lee et al. (2023) emphasize how AI-powered tools, particularly ChatGPT, support student-generated content and sustain interactive discussions in smart learning environments. Their study highlights the shift from AI as a mere information retrieval tool to a facilitator of student-driven knowledge exchange. The rise of asynchronous, AI-driven education models is reshaping higher learning landscapes. Pitso (2023) introduces the concept of *Telagogy*, a web-based, AI-enhanced learning framework, predicting that future education systems will function similarly to streaming platforms like Netflix, where students personalize their own learning experiences.

Automated assessment and feedback

GenAI tools are increasingly being used to automate the assessment process and provide real-time feedback to students, which helps reduce the workload for educators while improving assessment efficiency (Moorhouse & Kohnke, 2024). Beyond traditional AI-assisted learning, Pitso (2023) argues that asynchronous AI-enhanced education fosters greater student autonomy and engagement. The study highlights ChatGPT's role in accelerating assignment completion and improving students' problem-solving capabilities, demonstrating the growing reliance on AI for academic tasks.

Language learning with AI tools

Tools like ChatGPT have proven effective in supporting language learning, offering real-time corrections and feedback for learners (Moorhouse & Kohnke, 2024). This trend is expected to grow as AI models become more sophisticated and customizable for specific learning environments. While AI gamification fosters adaptive learning, concerns remain regarding over-reliance on AI tools and equitable access to technology. Pellas (2023) highlights that students using AI-assisted storytelling tools exhibit higher levels of engagement, improved ability to structure narratives, and greater confidence in their writing abilities compared to those using conventional platforms. Sian et al. (2024) stress the need for structured AI governance to ensure a balanced integration between AI support and human creativity. Moorhouse (2024) suggest that AI training should be embedded within initial teacher education (ITE) programs, providing pre-service teachers with hands-on experience in AI-driven instructional design, prompt engineering, and critical AI literacy. By doing so, educators will be better equipped to harness AI's benefits for adaptive learning while mitigating risks associated with plagiarism and AI dependence.

Ethical Concerns and the Digital Divide

While GenAI holds significant potential, it also raises important ethical concerns, particularly regarding data privacy and algorithmic bias. As Dimitriadou and colleagues (2023) pointed out, AI systems trained on biased datasets can perpetuate existing inequalities, leading to unfair treatment of students from underrepresented groups. Moreover, the reliance on AI in education could exacerbate the digital divide, as schools with fewer resources may struggle to implement advanced AI technologies (Garlinska et al., 2023). This highlights the need for clear guidelines and policies to ensure that AI is used responsibly and equitably in educational contexts.

Future Directions and Research Implications

The results of this study contribute significantly to the growing body of knowledge on the role of GenAI in education. However, there is still much to explore, particularly in terms of long-term impacts on learning outcomes, teacher-student interaction, and equity in AI-driven education. Future research should focus on optimizing AI applications to maximize their benefits for diverse learners while addressing ethical concerns. Moreover, the development of robust regulatory frameworks will be essential to guide the responsible use of AI in educational settings (Dimitriadou & Lanitis, 2023).

Ning et al. (2024) argue that AI-TPACK (Artificial Intelligence Technological Pedagogical Content Knowledge) serves as a foundational framework for equipping teachers with the necessary AI competencies. Their study emphasizes that ongoing AI training and professional development are essential for sustaining AI-driven educational transformations. Key trends include AI-driven personalized learning, gamification, automated LMS content generation, and ethical concerns regarding AI accuracy (Pesovski et al., 2024), highlighting the need for structured educator oversight and validation mechanisms. Educators and policymakers should promote interdisciplinary collaboration to leverage the strengths of both Applied Arts and Applied Science disciplines in innovation training (Sian et al., 2024).

CONCLUSION

This systematic review of GenAI in education from 2021 to 2024 highlights both the transformative potential and the challenges that accompany the integration of this technology in educational settings. The rapid increase in research publications reflects a growing interest in how GenAI can personalize learning and automate various educational processes. However, ethical concerns, including data privacy and algorithmic bias, remain significant challenges that need to be addressed to avoid exacerbating educational inequalities. Geographical

analysis reveals that countries like the United States, the United Kingdom, and Singapore are driving research in this area, while international collaboration plays a critical role in advancing the field.

Looking forward, while GenAI holds promise in revolutionizing education, its widespread adoption requires careful consideration of the ethical implications and the digital divide. Future research should focus on optimizing GenAI applications to enhance diverse learning outcomes while ensuring equitable access across different educational contexts. Additionally, the development of robust regulatory frameworks will be essential to guide the responsible and fair use of AI in education. The success of GenAI in educational systems ultimately hinges on global cooperation, clear policies, and ongoing dialogue between educators, policymakers, and technologists.

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Ethical statement: The authors stated that, as this research is a systematic review and does not involve any human or live subjects, no ethical approval for human subject research or informed consent is required. This aligns with the ethical guidelines for secondary data review. However, if secondary data or prior publications involve sensitive information, they are cited and acknowledged accordingly.

Declaration of interest: There are no financial, personal, or professional interests that could be construed as competing interests in the research conducted.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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