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A Systematic Review of Gen-AI Applications in Education: Rewards, Challenges and Future Prospects

Everleen Nekesa Wanyonyi[1] and Millicent Kathambi Murithi[2]

Jaramogi Oginga Odinga University of Science and Technology, Kenya[1]
Murang'a University of Technology, Kenya[2]

Abstract

Recent advancements in Artificial Intelligence (AI), particularly in Generative AI, have significantly impacted various domains. Innovation of models such as ChatGPT, Bard, DALL-E, Midjourney, and DeepMind has transformed academia. The widespread use of AI systems has sparked debates on how to effectively train future-relevant competencies while maintaining learning integrity. The ability of GenAI algorithms to generate specific feedback on tests, quizzes, and assessments as an instructional instrument to support student success has been a significant motivator. With current challenges of insufficient academic resources, a freeze on teacher hiring, and a shortage of practice space in developing countries, GenAI has become a handy tool to save the situation. Despite this boost, GenAI has faced major academic and ethical controversies. This study uses the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology to conduct an exhaustive literature search highlighting GenAI's applications, benefits, challenges, and future prospects in the education sector. Key findings highlight the efficacy of enhancing the theoretical basis of AI in education and offer a promising avenue for educators and AI engineers to conduct collaborative research.

Keywords: GenAI, machine learning, artificial intelligence, education

Introduction

Advancements in computing technology have led to rapid changes in educational practices (Patterson, 2021). Consequently, the inception of Machine Learning (ML) technology in education has recently advanced and expanded, resulting in increasingly sophisticated technologies such as Generative Artificial Intelligence (GenAI). GenAI is a partially supervised or unsupervised machine learning framework that uses probabilities and statistics to create human-like imitations (Hu, 2023). In the year 2022, GenAI tools such as Stable Diffusion, DALL-E, and ChatGPT were made available to the general public. With this advancement, society has become more conscious of the existence of AI and how it might affect people's daily lives (Heaven, 2023; Lampropoulos et al., 2023). Stable Diffusion and DALL-E generate images and videos from users' textual prompts.

On the other hand, ChatGPT (Generative Pre-trained Transformer) is a chatbot that can generate and summarize texts and translate language. In addition, ChatGPT uses paragraphs of text and codes of blocks to respond to user queries (OpenAI, 2022). Models such as the autoencoder and variational autoencoder have been used in the music industry to produce new lyrics and Recurrent Neural Network (RNN) models. On the other hand, transformer networks have created new textual data in natural language processing (Yu & Guo, 2023). Several researchers have appreciated GenAI tools as beneficial assistive technologies for problem-solving and content production in education, despite concerns about the possible decline of human creativity and academic integrity (Ali, 2021; Popenici & Kerr, 2017; (Patterson, 2021); Sharples, 2023).

One of the worrying trends in education is the capability of Large Language Models

*Contact author: ewanyonyi@mut.ac.ke

(LLM) to comprehend and produce natural language source code and instructions. In light of this tendency, educators need to apply their pedagogical skills to handle obstacles and take advantage of the opportunities presented by modern technology. İpek et al., (2023) note that cognitive tasks in education have been advanced by integrating AI in education. Even though the change offers new possibilities, educators must be innovative in their adaptation to reduce AI's possible adverse effects, which results in a changing educational environment. By way of a quick evaluation, Lo (2023) noted that although GenAI can help teachers create course materials, make recommendations, act as a virtual tutor, and foster collaboration, problems such as producing inaccurate results and plagiarism are frequent, requiring educational institutions to update their assessment procedures and guidelines quickly. Yan et al., (2023) explained how LLMs are being used to automate tasks in education, including knowledge representation, feedback, content creation, instructional support, detection, grading, recommendation, and profiling/labeling. However, several pragmatic and ethical challenges have been identified, such as inadequate technological preparedness, lack of openness and reproducibility, and inadequate privacy and beneficence considerations. Bahroun et al., (2023) identified the crucial concerns of adopting technology, classroom layout, evaluation procedures, teaching languages, ethics, subject-specific education, learning objectives, student involvement, AI integration, and creative teaching methods. Pradana et al., (2023) note that AI could transform education through its ability to manage duties requiring expertise and original thought, like assigning grades and offering student counseling. Challenges like ensuring the accuracy and reliability of AI-generated responses, along with fears of replacing tutors, have also been identified. Although GenAI is utilized in educational settings as a teaching assistant, individualized tutor, assessment partner, and co-researcher, its accuracy, dependability, and academic integrity have been found to have potentially detrimental consequences on cognitive and social development.

The key findings of most research studies are the effectiveness of strengthening the theoretical underpinnings of GenAI in education and presenting a viable path for further cooperative study between educators and AI technologists. Based on these facts, an exhaustive literature search was conducted, illuminating GenAI's applications in the education sector at various academic levels. We also explore and highlight innovative advancements and provide a thorough and insightful analysis of the most recent developments in GenAI. The research questions for this study were formulated as follows:

1. What are the state-of-the-art applications of GenAI in education?

2. What concerns emerge from using GenAI in education?

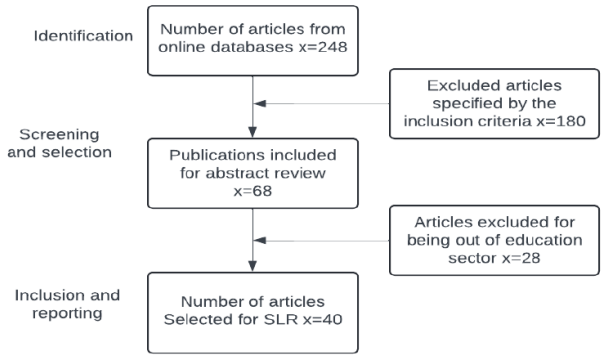
3. What future innovations/strategies can mitigate the challenges mentioned?

Methodology

This study aimed to gain a broader understanding of trends in using GenAI in education. The study adopted a systematic review approach guided by the Preferred Reporting Item for Systematic Reviews and Meta-Analyses (PRISMA) protocol. We used a content analysis approach to analyze GenAI's benefits, challenges, and prospects in education. The PRISMA process identifies the relevant literature by searching the databases using a systematic search strategy, followed by screening the identified records, whereby the inclusion and exclusion criteria for the publications are defined. The process concludes with a discussion of research findings. Figure 1 shows the process of identification of journal papers using PRISMA.

Figure 1

Selection and Review Process based on PRISMA



Search String and Query Space

A combination of specific keywords was used to search for articles from Scopus, IEEE, and ACM online libraries. Generative AI" OR "generative artificial intelligence," OR "GenAI" OR "GPT," OR "chatbot OR "Education," OR "Teaching," OR "Learning" were the key search words and phrases. "Generative AI in education" was the ultimate search phrase that defined most of the articles included in this study. The study included publications with the selected search strings in their titles that were available through library services or open access and indexed in respectable online libraries. These libraries were chosen because of their comprehensive coverage of publications, which enabled an inclusive approach.

Criteria for selection

Articles on GenAI in academia, regardless of education level, were included in the systematic literature review. Articles published between 2019 and 2024 were selected and included in this review. Quality assessment and selection criteria ensured that only the articles that were more relevant to the research questions were selected. The process was implemented as follows:

i. ***Screening.*** The subject area was limited to GenAI in education, and 180 articles from different subjects were excluded.

ii. ***Inclusion.*** Following the PRISMA protocol, 68 articles were included in the abstract review. During the abstract assessment, some articles were found to have been written in languages other than English, while others did not have adequate information to answer the research questions and were, therefore, removed, leaving 40 articles in the final research corpus.

Assessment on Quality

We used quality assessment parameters that took the following into account:

i. Reliable electronic scientific libraries were utilized to extract the relevant research materials.

ii. Only the most recent publications were considered to ascertain the highest-quality results.

iii. The PRISMA protocol for conducting a systematic literature review was strictly followed.

Results and Discussion

The use of GenAI in education has advanced significantly in recent years following the launch of ChatGPT in November 2022. It is noted that GenAI has been used as an intelligent teaching tool with the ability to generate personalized course content and teaching plans based on students' learning needs (Yu & Guo, 2023). Ghimire et al., (2024) also note that GenAI can automatically generate solutions, explanations, and examples for learning, reducing the instructor's effort. They further note that major LLM-based products like Generative Pre-trained Transformer (GPT-4), CodeX, GitHub Copilot, Bard, and ChatGPT significantly impact computing education research and practice.

GenAI applications can be summarized as the ability to automate tedious and routine processes, giving teachers more time to concentrate on more important facets of instruction. AI can be creatively used by educators to assist with assignment grading, provide tailored comments, develop exam questions, and identify biases and weaknesses in students' arguments. Lastly,

GenAI has been utilized to meet specific learning demands as a personal instructor.

What are the State-of-the-Art Applications of Gen-AI in Education?

The subsequent section answers research question one based on the following themes: Content creation, personalized learning, interactive educational tools, and collaborative learning. Since the 1960s, examples of GenAI in chatbots have been made available and used in various domains. However, in the last decade, the development of generative adversarial networks (GANs) in 2014 has highlighted the growing importance of GenAI in education (Goodfellow et al., 2020). The potential for GANs to reproduce and copy data distributions is enormous. They can also be trained to generate objects and artifacts that resemble the real world in various fields and topics. This advancement is highly disruptive to the academic landscape (Lee et al., 2023).

i. Content Creation/Generation

Researchers have demonstrated that GenAI is a tool for content creation in education. Large Language Modeling (LLMs) has been applied in education to automatically provide examples, explanations, and problem-solving answers to help students learn. This has tremendously reduced instructor effort during the learning process. However, there is a risk of incorrect solution propagation or explanation if not vetted (Ghimire et al., 2024). Academicians and educators can investigate and leverage the possibilities of GenAI with the help of various tools available on websites and specific portals, such as Futurepedia and All Things AI. Educators have enriched their pedagogical practices and promoted collaborative and personalized learning (Ruiz-Rojas et al., 2023). Fliki AI is an educational content-creation platform that enables the development of didactic resources, including interactive presentations, tests, and adaptive learning activities (*Fliki*, 2024). Finally, Aistudio.com has shown varying trends in video generation through the use of an AI avatar to generate realistic AI videos quickly and efficiently (Aigoogle, 2024).

ii. Personalized learning

Based on the learning needs of each student, an intelligent teaching system creates individualized lesson plans and course materials. Education has been affected by GenAI technology in several ways. Through interactive learning techniques, Duolingo, a free language-learning program built on GenAI technology, can transform language learning into a game that enables users to select new languages rapidly and joyfully. Additionally, Duolingo offers customers individualized learning plans, real-time feedback to better understand their learning issues and progress, and relevant guidance and support. The application can offer a customized learning experience by automatically modifying the material and level of difficulty according to the user's learning progress (OECD, 2023).

Squirrel AI is also an intelligent learning app that provides personalized learning plans and teaching content that caters to students' needs, learning progress and ability levels. The main components of Squirrel AI include intelligent diagnosis, personalized teaching, and real-time monitoring (Yu & Guo, 2023). Han et al., (2024) also noted that Generative AI can be used to generate adaptable teaching materials for teachers, enhance ideation, and provide students with personalized and timely feedback. Teachers can create and provide individualized, meaningful learning experiences by combining GenAI with an instructional design matrix. Using these tools, educators may improve the teaching-learning process and customize course materials to meet the needs of each student, ultimately preparing them for the challenges of the twenty-first century (Ruiz-Rojas et al., 2023).

Additionally, Jauhiainen and Guerra (2023) demonstrated how the Digileac platform may be utilized to access an excellent educational setting customized to satisfy the school curriculum requirements using a simple smartphone. ChatGPT-3.5 and 4 are examples of

how GenAI is used to personalize and customize learning materials to accommodate students with varying levels of understanding. Teachers utilize several IAG tools, including chatbots, You.com, chatPDF.com, and virtual assistants, to solve problems, obtain feedback, and explore new ideas. With these IAG technologies, student performance can be assessed more quickly and accurately (Kazemitabaar et al., 2023). ChatGPT has also shown significance in health education through personalized instruction, assistance with clinical reasoning, and improved understanding of complex subjects. Lastly, ChatGPT has been employed as a personal tutor, instrumental academic search tool, and source of inspiration (Kurtz et al., 2024).

iii. Programming Education

Finnie-Ansley et al., (2022) studied the capabilities of Codex, a Deep Learning (DL) model, to generate code as the output given a natural language problem as the input. Codex demonstrated dominance by outperforming students who took the test in a typical setting. In addition to translating code across programming languages, particularly in English, Codex may also explain the input code. Additionally, it was evident that the Codex-generated solutions varied, as the same input prompt often yielded significantly distinct solutions in terms of code length and the algorithmic approach.

Large language models (LLMs) have the capability to support students' learning by providing explanations for programming concepts given code snippets, and it was established that the learning experience is enhanced (MacNeil et al., 2022). Kohnke et al., (2023) discussed how generative ML may be a game changer in teaching creative programming by encouraging students to explore the tool's inconsistent actions and develop their programming skills.

Denny et al., (2023) investigated Copilot, an AI-driven tool for writing code to help users perform tasks efficiently. It can solve problems and prompt discussions to improve computational thinking abilities. According to their research, Copilot was able to solve 60% of the problems after modifying the problem description using natural language, and it was able to solve half of the difficulties in its first attempt. Kazemitabaar et al., (2023) demonstrated that AI code generators such as OpenAI Codex positively impact programmers. They saw gains in motivation, performance, and computational thinking ability. It was also shown that students who had access to Codex throughout the training phase performed comparatively better on the post-test evaluation, which was administered one week later.

The efficacy of generative pre-trained transformer (GPT) models was examined in tests that included multiple-choice questions about codes. Code snippet-containing queries were shown to be less successful than those that used only natural language. The most difficult questions seemed to require reasoning about the code, but they were addressed satisfactorily. In contrast, requests that asked for a natural language comment regarding the snippet or code blank were handled effectively (Savelka et al., 2023).

The performance and limitations of AI-powered programming are utilized as the GitHub Copilot in terms of creating code, providing explanations, creating tests, dealing with bugs, and encouraging findings (Wermelinger, 2023). Investigations were conducted on the benefits of integrating ChatGPT into programming instruction and how it affected students' motivation, computational thinking abilities, and self-efficacy (Ansari et al., 2023). The study backs the use of ChatGPT to enhance programming training classes (Yilmaz & Karaoglan, 2023).

The results of the studies mentioned above provide important new insights. First, researchers have shown how GenAI can significantly change the way creative programming is taught. Using GenAI can substantially change the teaching and learning of programming concepts. AI can enhance the understanding of complex programming concepts, as evidenced

by demonstrating LLMs' capacity to explain programming concepts. The benefits and challenges of integrating AI-powered code-generation tools such as Copilot in educational settings are also highlighted in these insightful viewpoints on the ramifications of such tools. By creating individualized lesson plans and course materials according to each student's unique learning requirements, GenAI has been utilized to provide personalized learning. Chatbots, Duolingo, Squirrel AI, You.com, chatPDF.com, and virtual assistants are tools that help with individualized learning.

iv. Higher education research/Co-designer

Additionally, through holistic analogical reasoning in postgraduate research activities, GenAI, particularly LLMs, has the potential to enhance STEM education (Rashid et al., 2024). Cao et al., (2023) discussed how GenAI simplifies complex programming, physics, and mathematics concepts into understandable analogies and converts them into visuals to improve learning. Through the provision of extensive knowledge and useful information on specific topics, these tools can help students improve their research skills. Students can use these sources to create preliminary sketches, systematized outlines, and summaries of their research subjects. These resources can also make writing easier for students and help them to grasp important ideas.

The application of AI in academic research has been demonstrated by empirical evidence that GenAI algorithms significantly reduce the time and effort required for systematic literature reviews (SLRs) by making it easier to recognize and classify articles. This is evidenced by Segura et al. (2023), who used the following GenAIs (Forefront, GetGPT, TheAI, Claude, Bard, and H2O) when classifying five hundred and ninety-six articles during the selection process of a systematic review of literature in healthcare education. The machine analyzed the contents more quickly than the manual methods. According to the report, postgraduate students face numerous difficulties when conducting research, including coming up with research subjects and devising solutions to specific issues. Opportunities for improving artistic abilities and experimenting with new forms of expression that are not possible through other apps can be found in GenAI. In the medical domain, LLMs are useful in replicating patient contacts and in preparing medical reports. Moreover, LLMs have been helpful in medical research by providing current information and formulating hypotheses based on available medical data. Previously, simulating such experiments was costly, dangerous, and time-consuming compared to now, when predictions are made within no time on a computer system. This can be applied to aviation and agriculture using digital twin technologies (Zang & Boulos, 2023). When students participate in collaborative creative projects such as creating websites, films, games, or physical products, they use GenAI tools throughout the design process to study user needs, define problems, question assumptions, discuss ideas, create prototypes, and test solutions (Sharples, 2023). This tool enables students to think faster and develop innovative problem-solving methods.

v. Education management

Large language models (LLMs) assist institutions in learning to deliver rapid solutions to administrative issues via chatbots. LLMs, for instance, can be used to respond to inquiries from possible candidates and provide them with precise information. In addition to providing administrative data such as timetables, examinations, and course descriptions, these models allow current students to register for classes. In addition, students can use chatbots driven by LLM to search for news and information related to their area of study. LLM-based chatbots can be developed to provide staff and international students with multilingual information. Additionally, LLMs can customize advertisements for educational opportunities based on several aspects, including the target demographic, age group, gender, and geography (Rashid et al., 2024).

Integrating LLMs and GenAI tools with curriculum management systems can significantly alter the monitoring and evaluation of educational programs (Ansari et al., 2023). LLMs such as GPT-4 can analyze data gathered from various sources, including student feedback, test scores, and program delivery statistics, to offer insightful information about the effectiveness of their programs. Finally, LLMs can identify improvement areas, monitor student performance trends, and provide standards for evaluating program performance (Abd-alrazaq et al., 2023).

What Concerns Emerge from Using GenAI in Education?

i. Academic Integrity and Innovation

Researchers have pointed out several advantages of GenAI. Notably, working with AI-generated code implies an accurate evaluation of the dependability and quality of the code produced by AI systems (Chan & Hu, 2023). Thus, identifying the drawbacks and moral dilemmas associated with GenAI in education is crucial. For instance, excessive dependence on automated coding could jeopardize students' comprehension of algorithms (Rashid et al., 2024). Furthermore, the research ignores the long-term impacts on problem-solving abilities and holistic learning in favor of immediate benefits in motivation and performance. However, its incorporation into educational environments presents questions about plagiarism detection, academic integrity, and the possible influence on critical thinking abilities. Potential negative effects on critical thinking and communication skills are also concerning (Kazemitabaar et al., 2023). The negative impacts of over-reliance on ChatGPT to perform assignments and quizzes have killed students' thinking capabilities (Kurtz et al., 2024).

ii. Inaccurate Predictions

Kurtz et al., (2024) posited that the main issues with using GenAI are biased and inaccurate information because AI naturally reflects imperfections in its training data. They also point out that careful supervision is necessary to ensure quality and identify errors because generative models can generate data, collect data from sources, and exhibit biased relationships. This is supported by Rashid et al., (2024), who worry about the GenAI's ability to manipulate or construct images and videos, resulting in incredibly realistic 'deepfakes,' presenting a unique challenge for educators and students. These "deepfakes" are becoming undetectable from actual content, making it easier to create and transmit fake news and other deceptive information.

Through an autoethnographic investigation, Stojanov (2023) investigated ChatGPT as a learning tool. The study highlighted the potential advantages of ChatGPT while noting its drawbacks, such as infrequent superficiality and inconsistent responses that it occasionally generates. It highlights the necessity of exercising caution and undertaking further studies to completely comprehend the implications of using ChatGPT in educational settings. GenAI creates content that deviates significantly from reality, relying more on its judgments than accurately depicting information. These hallucinations occur because AI systems, in their current form, lack adequate awareness and comprehension (Rawte et al., 2023).

iii. Privacy and security of Personal Identity Information (PII) Data

Data privacy and security concerns may arise because GenAI requires a large amount of data to train its models, such as academic records and personal identifiable information. Data security and privacy are severely affected if they are misused or disclosed. Potential bias in generated content especially on new data that was not used for training has also been a major concern (Kazemitabaar et al., 2023)

iv. Ethical concerns about Equity and Fairness

An ethical strategy for incorporating GenAI into education should consider both equity and accessibility. It is crucial to ensure that

AI does not worsen existing educational inequities in the classroom. Effective solutions for ensuring equal access to AI technology must be developed to narrow the achievement gap and prevent the digital divide from expanding. This comprehensive strategy ensures that learners from varied backgrounds can equally benefit from developments in educational technology; otherwise, there will be biases in basic education (Rashid et al., 2024).

Inadequate Resources. Faiz et al., (2024) realized that developing massive GenAI models has significant economic and ecological implications. These models require enormous computational resources, resulting in substantial energy consumption and carbon dioxide (CO2) emissions. These models have demonstrated outstanding performance across a variety of natural language processing tasks. However, because of their excessive energy consumption, their increasing scale has created concerns about their economic and environmental implications and deployment challenges. As industries move toward more complex and capable models, managing these costs and their environmental effects is becoming increasingly important (Chan & Hu, 2023).

Lack of Emotions. Current LLMs cannot replicate the degree of interpersonal engagement a real teacher or tutor offers. This is because their current capabilities are restricted to textual interfaces, they are unable to portray emotions, and they cannot understand students' and teachers' body gestures or movements (Abd-alrazaq et al., 2023). Phung et al., (2023) compared ChatGPT versions with human performance in various aspects. They realized that GPT-4 outperformed ChatGPT GPT-3.5 and was comparable to human tutors in numerous instances. However, ChatGPT-4's performance in grading feedback and task synthesis was significantly lower than that of the human tutors, highlighting areas for improvement.

Biased algorithms. Based on the work of Abd-alrazaq et al., (2023), GenAI models, such as ChatGPT, are developed using data from the internet, which can include webpages, books, news articles, scientific papers, and movie subtitles. Suppose data from a specific ethnic group are used to train a model. In that case, the machine's predictions may be biased and focus solely on the ethnic group from which the training data originated. For instance, results from an LLM trained on a large corpus of online content revealed gender bias (Ahn, 2023).

Which Future Innovations/Strategies Can Mitigate the Aforementioned Challenges?

Future studies should address academic integrity, assessment difficulties, and innovative approaches to integrating GenAI into academia while balancing the advantages and disadvantages of this integration. Addressing these difficulties requires diverse strategies.

i. Curated training data

AI models can detect and mitigate biases in materials created through training on regulated sources of knowledge. AI algorithms can identify biases in information, provide balanced alternatives, and regularly update and improve collected sources of knowledge through active learning. AI systems can also seek human approval for confusing or novel information, leading to higher-quality curated knowledge (Rawte et al., 2023).

ii. Ethical rules and policies

Future research may include establishing ethical rules and legal frameworks for using vetted information sources in AI research. This could promote responsible and transparent use of curated knowledge, thereby reducing possible hazards. Integrating knowledge graphs and vetted knowledge bases helps improve AI models' grasp of facts and the connections between ideas. This can improve content creation and fact-checking (Rawte et al., 2023).

iii. Integrating humans for verification

The integration of humans for verification is made possible through reinforcement learning with human feedback (RLHF). This approach

upgrades AI models using human experts' assessments of their outputs. The incorporation of human feedback tools into AI systems is essential for identifying and removing bias and error. Encouraging educators and users to report and correct inaccurate and biased information would increase the fairness and dependability of the system. This feedback loop is essential for creating an AI ecosystem that is sensitive to its users' various requirements and beliefs and is reflective, allowing for an inclusive, egalitarian learning environment based on ethical principles (Rashid et al., 2024).

iv. Environmentally friendly models

Mitra et al., (2023) adopted Smaller Language Models (SLM) for environmental solutions. An SLM is a language-processing AI version with fewer parameters than multifaceted models. The behavior of a model is determined by parameters learned from training data in machine learning and artificial intelligence. It is easier to deploy smaller language models on devices with lower processing capacity, such as mobile phones or embedded systems, because they are designed to be lighter and more effective. Smaller language models may not perform as well or accurately as larger models of complicated language tasks. However, they can classify tasks, human-like text generation, and comprehension.

Conclusion

GenAI has emerged as a rapid technological advancement, transforming various aspects of human life. This review paper analyzed how GenAI has transformed education in three main aspects: the state-of-the-art applications, the main concerns that emerge from the applications of GenAI in education, and the future innovations that can mitigate the challenges outlined. It is evident that GenAI's versatile applications in education enhance teaching and learning through content creation, assessment, personalized learning, and programming education. GenAI has proven to be an effective teaching and learning tool in programming. Numerous tools, such as Copilot, have enabled the generation of code and the teaching of creative programming. Students have created creative answers by utilizing text-generation models and chatbots. Additionally, chatPDF.com, You.com, chatbots, Duolingo, Squirrel AI, and virtual assistants are tools found to be very helpful in personalized learning.

The use of GenAI in education has generated debates about creativity, ethics, academic integrity, poor forecasting, lack of resources, and how it might change teaching and learning. Future research should weigh the advantages and disadvantages of GenAI integration to address the issues of academic integrity, assessment difficulties, and creative ways to integrate AI-generated code into programming courses.

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