A review of generative AI in digital education: transforming learning, teaching, and assessment

Gang Wang* and Fang Sun

School of Education,
Huainan Normal University,
Huainan, 232038, Anhui, China
Email: hnnu_wg@126.com
Email: sf@etthink.com
*Corresponding author

Abstract: The key to digital education in the current time is generated artificial intelligence (GAI), which allows personalisation as per learning, automated content generation, and novel assessment methods. Traditional education does not have enough flexibility or engagement to cater to learners' specific individual needs. In this thesis, we investigate GAI's role in the intelligent shape teaching takes through innovative systems, AI-generated content, and real-time assessment. It also checks platforms such as Khan Academy's AI tutor, Duolingo's conversational AI, and AI plagiarism detection. Adaptive curricula, emotion-aware tutors, and VR integrated AI are on the emerging trends. Nevertheless, there are a few challenges namely bias, privacy concerns and teacher displacement. These need to be addressed by ethics frameworks, data protection policies and AI human collaborative teaching models. In the conclusion, the study argues that GAI facilitates education in terms, and in the process, it can lift accessibility and cost of education thereby it in a way it should be incorporated in education to achieve fairness, transparency and academic integrity. AI-human collaboration should be further refined in future research for an ethnically and ethically inclusive and learning environment.

Keywords: generative AI; digital education; personalised learning; AI-driven tutoring; automated assessment; adaptive learning; AI ethics in education.

Biographical notes: Gang Wang is affiliated with the School of Education at Huainan Normal University, located in Huainan, Anhui, China. His academic interests focus on educational theory and practice, contributing to the development of effective teaching methodologies. With a commitment to advancing education, he actively engages in research and scholarly activities within the field.

Fang Sun is a faculty member at the School of Education, Huainan Normal University, in Huainan, Anhui, China. His work centres on educational research and teaching innovation. He is dedicated to improving learning outcomes through evidence-based educational practices.

1 Introduction

Artificial intelligence (AI), in general, and specifically generated artificial intelligence (GAI), is changing and can change many sectors rapidly (Kar et al., 2023). Its application in education can revolutionise learning and teaching in those areas. One of the traditional ways of imparting education is using a standardised curriculum, fixed learning materials, and instructor-based teaching methodology (Madavan, 2022). These often fail to cater to the varied needs of the students. Nowadays, digital education has become popular because of the increasing use of online learning, and advancing technology has made it possible to get remote content online and learn self-paced (Ebbini, 2023). However, digital education still has a long way to go in addressing several limitations facing digital education today, including lack of personalisation, limited student engagement, poor assessment methods, etc.

To solve these problems, GAI provides technologies for dynamic content creation, real-time tutoring, and automated assessment (Kumar et al., 2023). Unlike conventional AI based on pre-defined answers and rules automation, generative models, like OpenAI's GPT-4, Google's Bard and Meta's LLaMA, generate human-like text, interactive learning resources, and adaptive assessments that are customised to learners individuals (Raiaan et al., 2024). Further, these AI models enhance digital education by making the testing process more convenient, easier, and effective. Students can interact with AI-powered tutors and receive personalised feedback (Srinivasa et al., 2022; Ali et al., 2024). Also, with GAI, they have access to dynamically generated educational resources tailored to their personal learning needs.

1.1 The evolution of digital education and AI's role

Over the last few decades, technology has been integrated into education. Before the 2000s, the initial phases of early digital learning were limited to digital learning systems (learning management systems or LMS) that served static educational content and minimal interaction (Turnbull et al., 2020; Berking and Gallagher, 2013). One of the things that happened in the 2010s was the rise of intelligent educational technology with machine learning-based adaptive learning platforms, automated grading systems, and AI-powered virtual assistants (Chakraborty et al., 2024; Kavitha et al., 2023). While there, these systems were necessarily a bit reactive, being able to personalise learning only within some given parameters. In the age of GAI, we are witnessing this proactive and dynamic shift towards GAI as an operating system in the education system (Tanweer and Ismail, 2024). The three key phases of digital education are compared in Table 1, which points out passive AI applications and GAI as key differences.

Compared to other AI-based educational tools, GAI can dynamically generate educational content, contextually assist in real-time, and personalise learning. In the modern hybrid and online learning era, students need more interactive and flexible learning environments to achieve this capability.

1.2 Problem statement

Although some great leaps have been made in digital education, traditional e-learning methodologies still have significant limitations. The first problem is the absence of personalised online courses, which are taught in a standard way and fail to tailor their

lessons according to individuals' needs and learning preferences. Furthermore, there is a lack of real-time interaction with instructors and students; hence, engagement is low. In digital education, assessments usually do not take a form beyond multiple-choice quizzes and automated grading, which does not allow for meaningful and detailed feedback. Moreover, educators find it difficult to quickly generate a high-quality learning material, which increases the workload and the time for the course delivery. When tackling these limitations, GAI steps in as a personalised tutoring, real-time engagement, AI-driven feedback, and automated content creation tool. The key challenges in digital education and how GAI can bring potential solutions are summarised in Table 2.

Table 1   Evolution of digital education and AI's role

Phase	Description	Key technologies
Early digital learning (1990s–2000s)	Static e-learning content, pre-recorded lectures, and basic quizzes	Learning management systems (Moodle, black-board), web-based learning, flash-based modules
Intelligent EdTech (2010s–2020s)	Adaptive learning, chatbot tutors, and automated grading	NLP-based AI, machine learning, rule-based AI tutors, and adaptive learning platforms (DreamBox, Knewton)
Generative AI in education (2020s–present)	AI-generated interactive content, real-time tutoring, and dynamic assessments	Transformer-based AI models (GPT, Bard, LLa-MA), intelligent tutoring systems, AI-generated textbooks, AI-assisted grading, and multimodal learning tools

Table 2   Challenges in digital education and AI-driven solutions

Challenge	Traditional digital education	Generative AI solution
Lack of personalisation	One-size-fits-all approach	AI-driven adaptive learning that adjusts to student progress
Limited engagement	Static content, pre-recorded lectures	Interactive AI tutors and real-time virtual assistants
Inefficient assessments	Basic automated grading with limited feedback	AI-powered grading with detailed, contextual feed-back
Content creation bottlenecks	Manual creation of lesson plans and study materials	Automated lesson generation and AI-generated textbooks

But when it comes to digital education, GAI opens up a substantial opportunity to solve education issues, increase achievement through learning outcomes, reduce workloads for educators, and create more engaging learning experiences for students. To know whether GAI can be adopted in education, ethical and regulatory concerns should be addressed to ensure responsible implementation.

1.3 Research objectives

This paper investigates how GAI has transformed digital education and its pros and cons. The specific objectives of this study are:

- Study of GAI in improving personalised learning experiences by building AI-enabled adaptive teaching models.

- Beneath the surface of what AI-generated content can offer educators in lesson planning, assessment automation, and designing is an analysis of the pros and cons of the technique.

- It explores ethical and regulatory issues that arise in using AI in education: data privacy, bias, misinformation, and continuing human instructors as players in the education system.

- Critical factors must be considered for successfully embedding GAI in the digital education frameworks to enjoy its benefits while limiting its risks.

This research's insights are geared towards educators, policymakers, and technology developers who aim to adopt AI-based solutions in educational settings.

1.4   Scope of the study

This paper looks at the scope of GAI applications, ranging from higher education to K-12 education, corporate training, and self-paced online courses. However, this study also tackles ethical issues related to embedding GAI in digital learning, like bias in AI-generated content, misinformation risks, and AI-driven automation's ramifications on teachers and students. Figure 1 shows how AI-powered educational tools work with students, teachers and online learning platforms to illustrate the AI-driven digital learning ecosystem.

Figure 1   AI-driven digital learning ecosystem (see online version for colours)
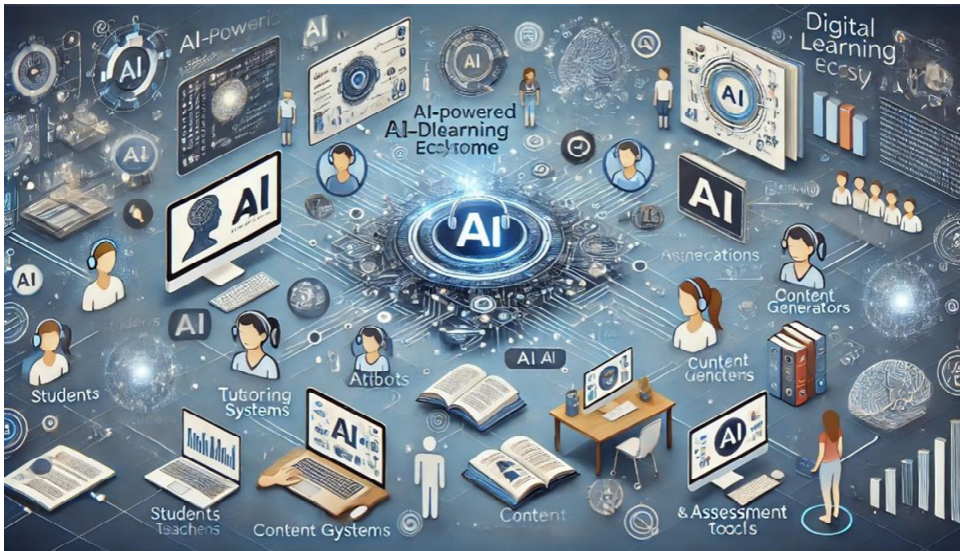
1.5   Organisation of the paper

In this paper, we structure it as such. Section 2 offers a brief history of GAI in education, starting with early digitally-based learning tools and ending up in present-day AI-powered platforms. Section 3 explores GAI's impacts on learning and teaching

paradigms, specifically at the front of personalised education, intelligent tutoring systems and AI-assisted content creation. Section 4 investigates key challenges and related ethical issues such as AI bias, misinformation, teacher roles, and data privacy concerns. Finally, in Section 5, real-world case studies of AI-driven education tools like AI-driven tutoring systems and AI-generated books. The last section, Section 6, outlines future research directions and concludes with remarks on GAI in digital education.

1.6   Summary

GAI redefines how digital education is utilised, making it more personalised, generating content automatically, and enhancing student engagement. However, integrating AI into education continues to present challenges, notably bias in AI-generated content, data privacy, and the new definition of the role of human educator. Organised for students, this study studies their impacts on education and its positives and negatives. The future work will improve AI human collaboration in education to make it a more efficient, inclusive learning system. This section lays the foundation; the next section looks at how GAI has developed in education, examining the history of AI learning technologies.

2   Evolution of GAI in education

Over the past few decades, AI has helped transform education, which is quite apparent (Zhai et al., 2021). The first applications of AI in education primarily addressed administrative chores, adaptive learning systems and rule-based tutoring programs (Singh et al., 2025). Early systems could give feedback, evaluate the student's performance, and suggest study materials according to pre-defined rules and heuristics (Roscoe and Craig, 2022). Despite this, they could not produce dynamic content or have real-time interactions with their students.

As NLP, deep learning, and transformer architecture changed from passing specific information back and forth through a network to generating human-like feedback responses to educational content and assisting students with problem-solving tasks, AI has become a sophisticated system (Sridharan et al., 2024a, 2024b; Campino, 2024). GAI's arrival brings a new era in educational technology. It introduces the ability of AI to generate learning materials, personalise learning routes, and provide interactive tutoring (Tanweer and Ismail, 2024; Suresh et al., 2025; Godwin-Jones, 2024). AI in education has evolved from simple automated systems to dynamic generative models that adapt to students' needs and enhance learning engagement.

2.1   Historical development of AI in education

AI in education has followed three successive stages. Early digital learning (1990s–2000s) brought the first phase of online learning platforms: essential platforms that digitised course materials and automated grading systems (Dimitrov et al., 2019; Mammadova, 2023). We refer to Moodle and Blackboard, which provide static pre-defined learning content with poor adaption. The period in which intelligent educational technology emerged (2010s–2020s) established AI initiatives which allowed the personalisation of the learning process by analysing a student's performance and later by adapting course recommendations (Slattery, 2024; Macgilchrist et al., 2020;

Williamson and Eynon, 2020). The next phase in AI in education is the generation in education (2020s), with AI models producing educational content, real-time tutoring, and contextually engaging with students (Chiu, 2024; Paiz et al., 2025; Chakraborty, 2024; Pratschke, 2024). Table 3 summarises the historical evolution of AI in education, describing major characteristics and technical advances in each phase.

Table 3 Evolution of AI in education

| Phase	Characteristics	Key technologies
Early digital learning (1990s–2000s)	Static e-learning content, automated grading, limited interaction	Learning management systems (LMS), rule-based AI, and web-based education
Intelligent educational technology (2010s–2020s)	AI-powered personalised learning, automated tutoring, and adaptive assessments	Machine learning, NLP, AI-based recommendation systems
Generative AI in education (2020s–present)	AI-generated interactive content, real-time tutoring, and dynamic assessments	Transformer-based AI models (GPT-4, Bard, LLaMA), generative AI, AI-powered chatbots

However, GAI breaks new ground because it extends beyond automating and personalising and empowers data scientists to be freed from the burden of data preparation. Generative models are generative, in contrast to AI applications that mainly deal with existing content, generating structured responses, developing new content dynamically, simulating human-like interactions, and tailoring learning materials to individual student needs.

2.2 The role of GAI in modern education

Transformer-based models like GPT 4 (OpenAI), Bard (Google), and LLaMA (Meta) have introduced transformer-based models that have revolutionised the learning experiences via AI-driven learning (Raiaan et al., 2024; Annepaka and Pakray, 2024; Hadi et al., 2023, 2025). Deep learning and large datasets enabled these models to understand and sometimes generate human-like text, which makes them very effective tutors, content creators, and student engagement (Khosravi et al., 2023; Sridharan et al., 2024a; Attard and Dingli, 2024). Unlike a typical AI learning system, GAI models can interpret context, explain in detail and create personalised learning materials in real-time (Yan et al., 2024b; Pang and Wei, 2025; Yu and Guo, 2023).

AI-assisted content generation is one of education's biggest GAI applications (Banjade et al., 2024; Alasadi and Baiz, 2023; Borger et al., 2023). AI-powered tools enable educators to make custom lesson plans, create quizzes, configure interactive assignments, and tailor study guides based on the subjects and the student's skill levels (Almuhanna, 2024; Makinde et al., 2024; Srinivasa et al., 2022; George, 2023). It is an automation that removes the load from the teacher and makes the teacher focus on more interactive teaching and student engagement. AI-generated textbooks and study materials also provide an affordable alternative to traditional publishing, allowing access to quality educational resources more widely (Almuhanna, 2024; Panke, 2024; Tila and Levy, 2023). Figure 2 shows how GAI is incorporated into modern education, including content creation, real-time tutoring, and personalised learning patterns.

Figure 2   The role of GAI in modern education (see online version for colours)
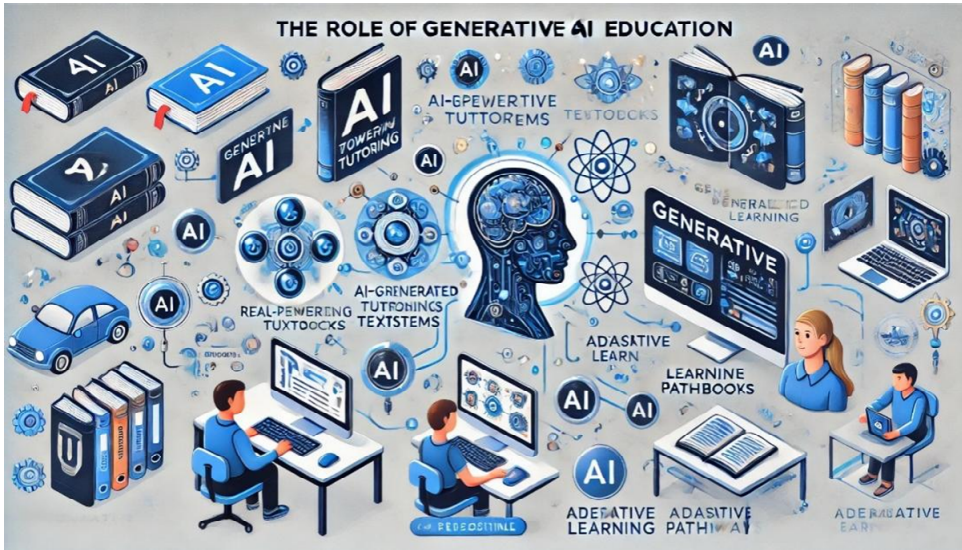
An AI-driven tutoring system will provide instant explanations, answers to student questions, and responsiveness to students' increasing understanding (Liu et al., 2023). GAI, on the other hand, differs from static online courses as students have trouble finding answers to specific questions. In contrast, there's an ability to interact with and have conversations with. Such a level of engagement aids knowledge retention, problem-solving skills and overall learning efficiency.

Automated assessment and feedback is another significant advancement made possible by GAI. Multiple choice tests and even standardised exams give little insight into how the students understand the contents. Com GAI can analyse essays, problem-solving approaches and open-ended answers. It provides detailed feedback on helping students improve their critical thinking and analytical skills (Ruiz-Rojas et al., 2024; Gonsalves, 2024; Fan et al., 2025). AI-powered grading systems can also identify patterns in student errors, suggest different practice exercises based on student errors and track student progress over time (Giri, 2025). Table 4 presents a comparative analysis of GAI from the traditional AI application in education, relevant to their transformative abilities.

Table 4   Comparison of traditional AI and GAI in education

Feature	Traditional AI	Generative AI
Content creation	Static, pre-programmed	AI-generated dynamic content
Personalisation	Limited adaptability	Highly adaptive, real-time customisation
Tutoring interaction	Rule-based, limited responses	Conversational, context-aware responses
Assessment	Automated grading with pre-defined rubrics	AI-powered grading with detailed, context-aware feedback
Student engagement	Passive learning	Interactive, personalised learning experiences

Table 4 shows that GAI provides a better interactive, personalised, and efficient learning experience than traditional AI educational tools. Generative learning creates a more significant and dynamic learning side by allowing students to engage in real-time discussions, get contextual feedback, and access AI-generated study materials.

2.3 Challenges and future directions

Despite its benefits, the use of GAI within education is complicated. The main problem stems from bias in AI-generated content, as generative models are trained on massive data sets that might include biased or wrong information. AI-driven learning should ensure fairness and accuracy in AI-generated educational materials to maintain the credibility and inclusivity of AI-driven learning. The second major challenge is data privacy and security, as data are a crucial need for AI-generated education platforms to personalise learners' experiences. To protect students' information, institutions must do a good job of implementing robust data protection measures to comply with educational regulations.

The other consideration is the role of teaching in a classroom with AI. GAI can help improve how content is delivered and assessed but cannot replace the work of human educators in supporting critical thinking, creativity, and ethical decision-making. Integrating AI as an assistive tool that supports human instruction rather than trying to replace it is the ideal approach.

Future research should optimise human-AI collaboration in education to maintain the ethics, effectiveness, and inclusiveness of AI-based learning environments. To generate this form of AI as it evolves, it has the potential to close geographic learning and education gaps, open access to quality education, and build personalised learning paths based on every student's needs.

2.4 Summary

The evolution of AI in education has evolved from simple rule-based automation to GAI models that can create dynamic educational content, provide real-time tutoring, and deliver personalised learning experiences. The GAI aspect in digital education is a significant paradigm that provides an adaptive learning path, interactive assessment, and study of AI. While it is also taken up, ethical and related regulatory issues need to help mitigate against it. The following section will explore three GAI applications – learning and teaching paradigms – that will bring us deeper insight into GAI's application and implications in modern education.

3 Transforming learning and teaching paradigms

GAI integration in education is turning norms of learning and teaching on its head. It differs from typical digital education models that rely on static course material, pre-defined assessments, and academic lectures provided by instructors (Liu et al., 2023; Kumar et al., 2023; Mittal et al., 2024). In contrast to the old way of doing things, GAI helps student engagement and educator efficiency by automating lesson planning, creating personalised learning materials, and intelligent tutoring services (Sandhu et al., 2024).

This focus on three fundamental shifts in learning and teaching paradigms is centred on transforming these paradigms through AI-driven technologies. For the first shift, AI's suiting educational content to a student's progress is strong and a good point (Al Nabhani et al., 2025). The second is AI-assisted content generation, which relieves the societal burden of educators by automating the creation of lesson plans, quizzes, and interactive exercises (Yadav, 2025). The third shift centres on AI-powered assessment and feedback systems (Moreira and Teles, 2024) that are not limited to grading the students but give students real-time contextual feedback to understand them better and memorise what they learned.

3.1   Personalised learning and student engagement

One of the most significant changes in GAI is moving away from standardised learning models to personalised learning pathways. Traditional classroom education is based on a fixed curriculum; all students learn using the same instructional content (Hong et al., 2023; Relan and Gillani, 1997; Walker and Schaffarzick, 1974). The risk with this approach is that students who cannot keep up will often fall behind, while those who are too easy will be bored and frustrated because they fail to learn. GAI solves this problem by customising learning experiences according to how students perform and engage, specifically, how the AI assesses the student's proficiency and enthusiasm (Qadir, 2025; Elmourabit et al., 2024; Sandhu et al., 2024).

Adaptive learning platforms based on AI are tuned to see student responses, identify problem areas, and reconcile the platformed lessons. Students do not follow a rigid syllabus but engage with AI tutors, who adjust the difficulty level of lessons, offer additional explanations, and generate custom practice exercises (Woolf, 2010; Khosravi et al., 2022; Saini et al., 2024). Table 5 reflects the main distinctions between AI-powered and traditional personal learning.

Table 5   Traditional learning vs. AI-powered personalised learning

Feature	Traditional learning	AI-powered personalised learning
Learning approach	One-size-fits-all curriculum	Adaptive, customised content for each student
Pacing	Fixed for all students	Adjusts based on individual progress
Feedback mechanism	Periodic exams and assignments	Real-time AI-driven feedback
Student engagement	Passive learning (lectures, textbooks)	Interactive and conversational AI tutors
Content modification	Limited flexibility	AI generates new study materials dynamically

Table 5 shows that AI-powered education shifted from passive learning to interactive, student-centric learning models. The transformation makes learner engagement through this as learners can progress at their own pace with individualised support. Figure 3 illustrates how GAI establishes personalised learning pathways by dynamically adapting the content according to student needs.

Figure 3 AI-driven personalised learning pathways (see online version for colours)
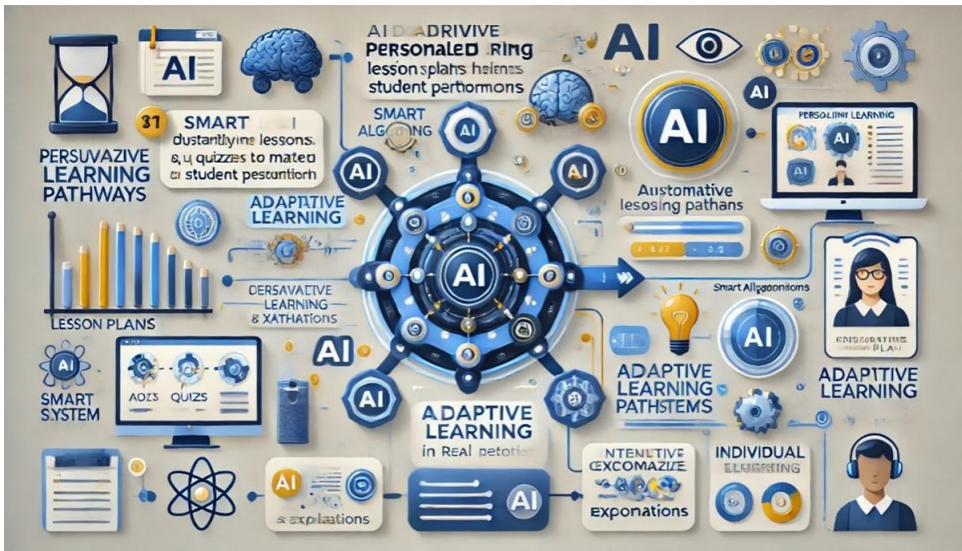
3.2 AI-assisted content creation for educators

Lesson planning, assessment design, and content creation are overly time-consuming processes, and educators are the ones who shape learning experiences. Traditional teaching methods rely on lecturers preparing their course materials on a per-basis, which is an inefficient and costly process for handling large numbers of students (Forrester et al., 2008; Yam, 2010). It offers solutions to generations of AI by creating lesson plans, assignments and instructional resources.

There are personalised quizzes, interactive exercises, and AI study guides generated by AI for a particular set of learning objectives. By putting key concepts into it, the AI models generate structured lecture notes, question banks, and video content related to the subject (Chen et al., 2020; Gm et al., 2024; Sundari et al., 2022). The automation eliminates the need for educators to work on financial statements manually and allows them to spend more time on interactive teaching and student mentorship. Table 6 assesses the difference between the manual content creation and AI-powered content generation for educational resources.

Table 6 Manual vs. AI-assisted content creation

Aspect	Manual content creation	AI-assisted content generation
Time required	High (hours to days)	Low (minutes)
Customisation	Limited to instructor input	AI-generated, adaptive to student needs
Content quality	It depends on the educator's expertise	AI ensures consistency and completeness
Scalability	Difficult for large-scale courses	Scalable for multiple subjects and levels
Engagement	Static materials (text-books, PDFs)	Interactive and multimedia-rich content

Content creation using AI makes education more efficient for educators by preserving the quality and individualisation of education. Consequently, teachers can have more time to dwell on student interaction, discussion-referenced learning, and mentoring instead of administrative commitments.

3.3   *AI-powered assessment and feedback*

It is recognised as an essential part of the learning process, but traditional assessments have several limitations. Standardised tests can miss more critical cognitive abilities, and grading many assignments is time-intensive. Automated assessment tools powered by AI can grade automatically, provide real-time feedback, and provide intelligent error analysis that increases the accuracy and speed of evaluations (Paiva et al., 2022; Moreira and Teles, 2024; Lu and Cutumisu, 2021).

In this case, GAI has the potential to evaluate essays, problem-solving exercises, coding assignments and others with more detailed feedback that goes beyond the simple right or wrong answers (Awidi, 2024; Cheng et al., 2025; Yan et al., 2024a; Saini et al., 2024; Zhai et al., 2024). AI grading systems help students understand what gaps in their thinking need to be filled to complete an assignment and learn from this feedback successfully (Hooda et al., 2022; Murphy, 2019; Chen et al., 2023). In contrast to the traditional surname, an AI-driven system can provide feedback while the student works, giving rise to a more interactive learning experience (Almusaed et al., 2023; Luckin and Holmes, 2016; Arya and Verma, 2024). Figure 4 shows how AI-powered assessment tools and errors that analyse student responses are detected, and real-time improvement recommendations are provided.

Figure 4   AI-powered assessment and feedback system (see online version for colours)

Differences between traditional assessment methods and AI-driven assessments are well presented in Table 7, highlighting that AI improves feedback quality and outcomes for students learning.

Table 7   Traditional vs. AI-powered assessment

Feature	Traditional assessment	AI-powered assessment
Grading speed	Slow (manual grading required)	Fast (automated AI-based grading)
Feedback type	Scores with limited explanations	Contextual feedback with detailed insights
Real-time suggestions	Not available	AI provides instant feedback as students work
Bias in grading	Subjective grading possible	AI ensures consistent evaluation
Adaptability	Static assessment format	AI modifies questions based on student performance

AI-powered assessment tools offload a good part of the burden from educators, leaving them with time for more meaningful interactions. The feedback is detailed and constructive and ultimately helps students to learn, do better, and understand what they did wrong.

3.4   Summary

GAI is changing the learning and teaching paradigms by providing personalised learning, enabling AI-assisted content creation and intelligent assessment systems. Unlike the standard educational model based on rigid curricula and manual grading, AI-powered education offers an adaptive learning experience, real-time feedback and scalable learning content production. Students can learn at their own pace, using personalised learning pathways, while AI generates content resources that help educators ease themselves and design lesson plans and assessments. AI-powered feedback mechanisms help students perform better through insights in context and real-time help.

However, despite these breakthroughs, there are concerns regarding the inclusion of GAI into education, such as AI bias, misinformation, and the metamorphosis of teachers in AI-based classrooms. The following section reviews the challenges and ethics of applying AI to education, particularly regarding data privacy, fairness and the long-term impact of AI on teaching methods.

4   Challenges and ethical considerations

GAI Integration in Education made significant changes in the Learning and teaching paradigm. On the one hand, AI-based education has advantages like personalised learning, automated content creation, and real-time feedback (Marengo and Pange, 2024). On the other hand, many challenges and ethical misgivings must be addressed for responsible implementation. The main difficulties revolving around these challenges are bias in AI-generated content, data privacy, misinformation risks, student dependence on AI, and how educators will begin to facilitate in this new area (especially considering it has not been around very long).

As AI models generate and curate education content, questions around accuracy, fairness and IP arise. Such misinformation will likely spread among students if AI-generated materials contain inherent biases or factual inaccuracies. In addition, utilising AI in education poses issues that disturb student privacy, data security, and the

ethics of treating private information. At the same time, AI-powered tutoring systems make learning more engaging. Still, they also present the possibility of relying too much on technology and undermining the development of thinking skills. It then deeply considers its use's primary issues and ethical concerns in education, outlining its risks, consequences, and potential solutions.

4.1   Bias in AI-generated educational content

Bias in AI-generated learning materials is one of the most pressing issues regarding AI-driven education. Vast datasets on which their AI models are trained are pulled into them from the internet, academic papers, and publicly available knowledge bases. Any datasets that include historical, cultural, or systemic biases, which the AI model is privy to, could inadvertently replicate and spread with the generated content. Such portrayal of life can lead to misrepresenting facts, gender or racial biases, and hence unfair learning outcomes, resulting in a student's point of view and learning.

There are various ways bias is present in AI-generated educational content. AI-generated explanations in history or social science courses may reflect a Western-centric point of view, including the philosophies of other cultures. Anticipated consequences of AI in social science and technology subjects include gender-biased recommendations that reinforce existing stereotypes about job roles. Table 8 shows different biases one can have in AI-generated educational material and can have within the students.

Table 8   Types of bias in AI-generated educational content

Type of bias	Description	Potential impact
Cultural bias	AI content favouring dominant cultural perspectives	Excludes diverse view-points, leading to a narrow understanding of topics
Gender bias	AI reinforces stereotypes about gender roles in professions and education	Limits career aspirations and interest in specific fields
Historical bias	AI favours particular historical narratives over others	Creates distorted perceptions of historical events
Socio-economic bias	AI content reflects the experiences of privileged groups	Disadvantages students from underrepresented backgrounds

Continuous monitoring and update of AI models will be required to address AI bias as training datasets need to be diverse and representative from various perspectives. In addition to this, educators will also have to act as a kind of GLA assessor and validate the AI-generated content before they can add it to the teaching material.

4.2   Risks of misinformation and AI hallucinations

A second major challenge to AI education based on AI is misinformation and AI hallucinations. Although GAI models can produce human-like responses, they do not have proper comprehension or the ability to verify their factual status. And in the case of AI hallucination, AI may fabricate information or produce misleading responses. It poses a fundamental risk to knowledge integrity in educational settings since students can

unawares base learning on erroneous or fabricated ways of thinking offered by the AI tutors.

It happens in subjects such as science, mathematics, and history where accuracy and precision are a must, reliance on fact, and where the promises of truth are non-existent. While students develop incorrect understandings if the formulae provided by AI are wrong, AI misinterprets scientific theories and distorts historical events, which could also affect their academic performance. It is why an example of how an AI hallucination could mislead students with the explanation of a mathematical concept is illustrated in Figure 5.

Figure 5 Example of AI hallucination in a math explanation (see online version for colours)
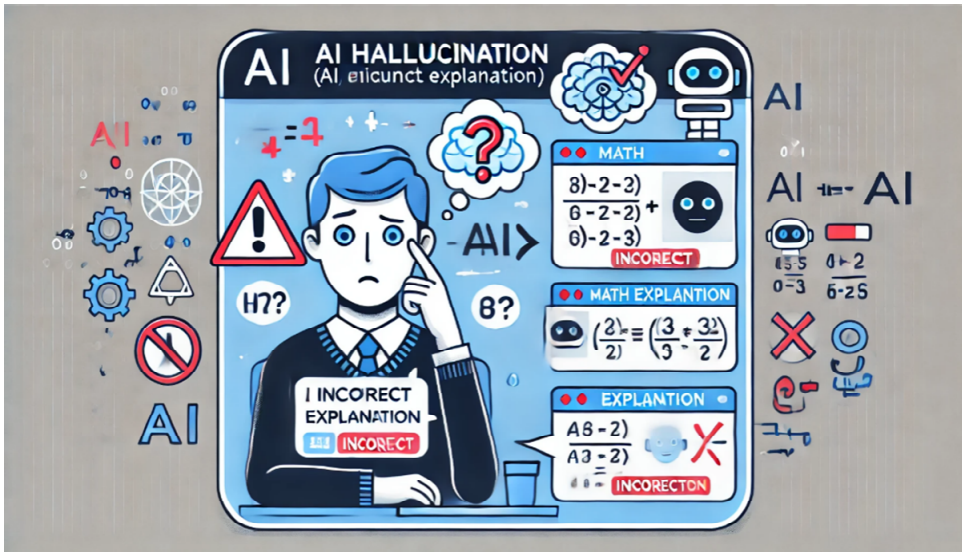
To minimise the dangers of misinformation, educational institutions need to equip their AI-generated content with a fact-checking system. The models should be designed to cite credible sources and undergo rigorous validation. In addition, students should be taught critical thinking skills to verify AI-generated explanations rather than automatically accepting them.

4.3   *Data privacy and security concerns*

AI education means gathering and investigating student information, such as data on learning advancement, scholastic execution, and conduct designs. While this data is necessary to engage in personalising learning experiences, these data present serious challenges to data privacy, data security, and data usage ethics. To ensure that schools and educational platforms using AI are abiding, they must comply with strict data protection regulations such as the General Data Protection Regulation (GDAR) and the Family Educational Rights and Privacy Act (FERPA), where personal student information must be protected. AI-driven education has data privacy concerns, such as unauthorised data access, possible data breaches, and unethical data usage by third

parties. Table 9 outlines AI's primary data privacy risks in education and their potential implications.

Table 9   Data privacy risks in AI-driven education

Risk	Description	Potential consequences
Unauthorised data collection	AI systems collect student data without explicit consent	Violation of privacy laws and ethical concerns
Data breaches	Exposure of sensitive student information due to cyberattacks	Identity theft, academic fraud, and misuse of personal data
Third-party data sharing	AI platforms share student data with external entities	Commercial exploitation of student information

To overcome these, educational institutions need to implement strong encryption measures, an anonymous data policy, and transparency regarding data. Concerning AI-driven educational tools, data access and usage should be in the hands of students and parents, and ethical and legal standards should be maintained by students and parents.

4.4   Over-reliance on AI and reduced critical thinking skills

AI-driven education helps in enhancing learning efficiency, but a worrying growth generally exists in student dependency on AI tools, which might also undermine the criticalness and problem-solving techniques. If students rely too much on AI-generated answers, they might become passive rather than active learners in analytical reasoning and independent problem-solving. While AI tutors and automated content generation can be over-reliant, this movement can limit the need for deep comprehension. Students may settle for instant AI replies rather than conventional research and mental work. In Figure 6, a contrast is made between active learning and AI-dependent learning, as the latter is a matter of concern, and critical thinking skills are likely to decrease.

Figure 6   Active learning vs. AI-dependent learning (see online version for colours)
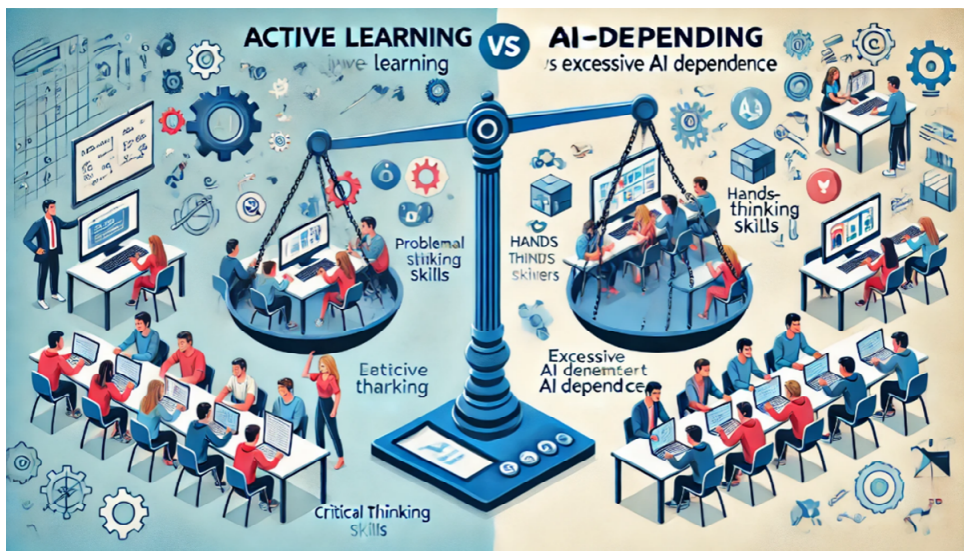
An educational framework should actively and consciously evolve to balance the use of AI with traditional learning methods to avoid overreliance on AI. Instead, teachers should encourage students to independently research independently and write critically the AI-generated answers. AI should be used as a supplementary learning aid for cognitive skills development.

4.5   Summary

There are many challenges and ethical considerations when integrating GAI in education. There is a need for proactive solutions to these issues that surround the use of AI in providing learning content, namely the risks of bias in AI-generated content, the risk of misinformation, privacy concerns around data used by AI, and the reliance of students on AI tools. The risks of AI-driven education can be minimised if fact-checking systems, robust data protection policies, and critical thinking education are implemented to maximise AI-driven education's benefits. In the next section, we dive into practicable applications of AI in education through the context of successful case studies in the real world.

5   Case studies: successful AI integration in education

GAI has successfully integrated into education by helping with personalised learning, automated assessments, intelligent tutoring, and content creation. AI technologies have been leveraged to provide various educational platforms and institutions to increase the engagement of students, boost learning outcomes, and streamline teaching processes. Real-world implementation of the effectiveness of AI-driven education can be better understood. The case studies in this section illustrate how AI-powered educational platforms have adopted GAI into their system. These case studies are chosen – Khan Academy's AI tutor, Duolingo's AI-driven language learning, AI-driven plagiarism detection systems, and OpenAI-generated textbooks. In these examples, we see the multitude of ways AI is being used in education to illustrate its positive and negative potential.

5.1   Case study 1: Khan Academy's AI-powered tutor

To personalise and improve the learning experience, Khan Academy, widely known as an online learning platform, has adopted and implemented AI-based tutoring systems into its processes. Khan Academy launched Khanmigo, an AI-powered virtual tutor in collaboration with OpenAI, offering real-time help, interactive problem-solving, and adaptive learning recommendations. It is an AI-powered tutor that analyses student responses, identifies weaknesses and generates tailored explanations to reinforce understanding. Khanmigo dynamically changes a lesson's difficulty and the question's complexity to match student performance. This feature has improved student engagement, increased retention rates, and enhanced Individualised Learning. Figure 7 shows how Khanmigo works for students by interactively explaining Khan Academy material.

Figure 7   Khan Academy's AI-powered tutor (Khanmigo) in action (see online version for colours)
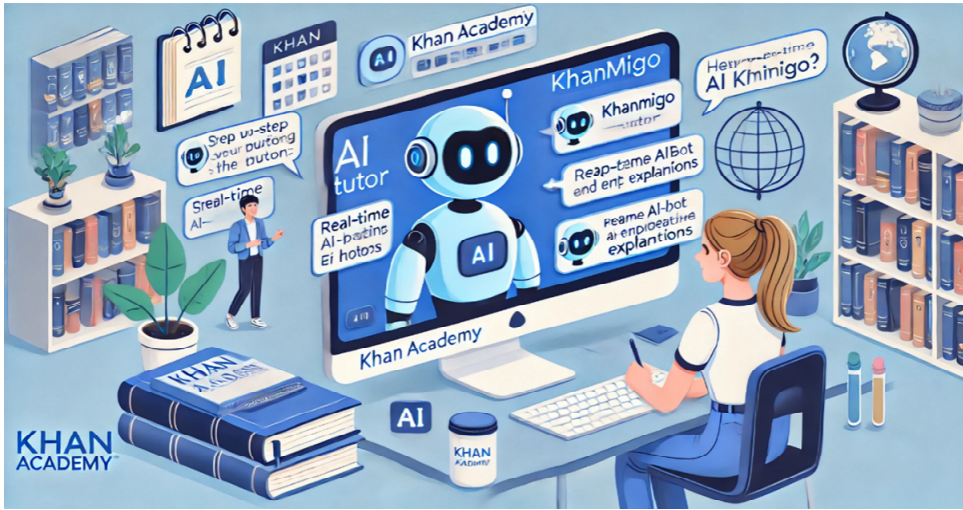
Khan Academy made a study of the method back in 2023. The result was that students who used Khanmigo for math and science classes (all the while not using Khanmigo) improved their problem-solving efficiency by 30% more than people using traditional self-paced learning methods. Key Performance Metrics of comparison on traditional tutoring vs. AI tutoring are presented in Table 10.

Table 10   Traditional vs. AI-powered tutoring at Khan Academy

Metric	Traditional tutoring	AI-powered tutoring (Khanmigo)
Student engagement	Moderate (limited interaction)	High (real-time adaptive feedback)
Content customisation	Pre-defined lessons	AI-generated personalised guidance
Tutor availability	Scheduled sessions	24/7 on-demand assistance
Performance improvement	10–15% average improvement	30% improvement in problem-solving skills

Integrating AI tutoring systems at Khan Academy shows the possibility of employing AI to increase learning efficiency, provide real-time feedback, and help students better understand the material on a large scale.

5.2   Case study 2: Duolingo's AI-driven language learning

The high demand for GAI models has led to the incorporation of GAI models by Duolingo, a famous language learning platform, to provide a personalised learning experience and a conversational AI tutor. AI-driven chatbots were used on the platform to simulate real-world conversations where learners could practice writing and speaking skills in an interactive and immersive setting. Duolingo's AI model uses deep learning to analyse user progress and naturally adjust lesson plans as users progress, focusing on proficiency levels, learning patterns, and error analysis. Although Duolingo is not a version of Memrise, the AI behind it – as opposed to the rigid exercises it promotes – does offer a unique gamification versus feedback mechanism that kicks in real-time once

you've built confidence and started to scale through the curriculum. Table 11 presents the differences in performance between traditional and AI-driven language learning.

Table 11 Traditional vs. AI-powered plagiarism detection

Feature	Traditional plagiarism detection	AI-powered plagiarism detection (turning in AI)
Detection accuracy	70–80%	95%+
AI-generated content detection	Limited capability	Advanced AI-authorship detection
Processing speed	Slower (database matching)	Faster (context-aware analysis)
Adaptability	Fixed algorithms	AI adapts to new writing patterns

It implements AI software for plagiarism detection, positively affecting academic honesty and content originality in universities and research institutions. Figure 8 shows how AI-based plagiarism detection systems work to detect plagiarism between academic papers and uniquely mimic the AI-generated scripts and paraphrasing patterns.

Figure 8 AI-powered plagiarism detection system in action (see online version for colours)
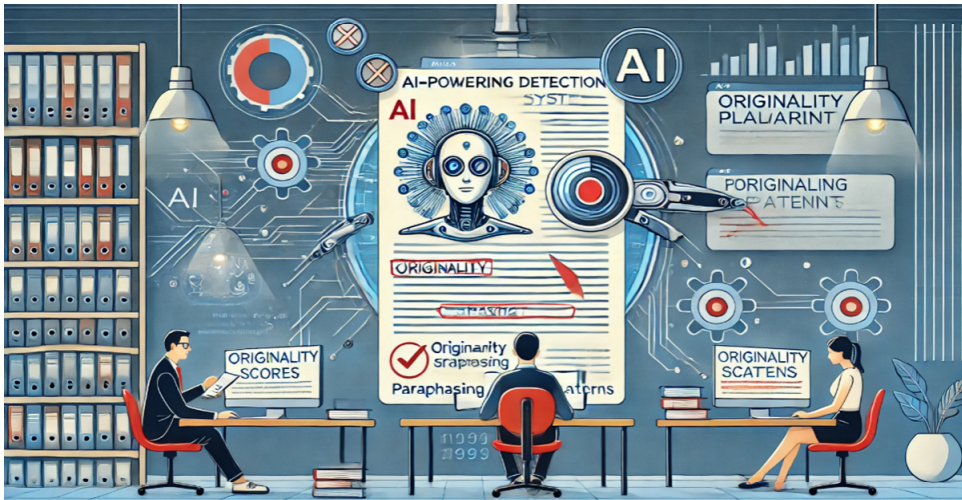
5.3 Summary

As a result of the integration of AI in education, education has improved dramatically in terms of personalised learning, language acquisition, and academic integrity. Khan Academy's AI-powered tutor has shown that it is better at student engagement and problem-solving in more in-depth parting, and Duolingo's AI-driven language learning has learned to enhance retention of the language through interactive conversation. Academic integrity has been strengthened through AI-powered plagiarism detection systems that detect AI-generated content and guarantee originality. The case studies show how AI is used in various education applications, from enhancing learning outcomes to automating assessments and optimising teaching methodologies. Nevertheless, the implications of the ethical considerations and challenges raised in the preceding section to prevent irresponsible and unfair use of AI in education must be seriously considered.

The following section will look forward to AI's possible future and advancements in AI-driven education. It will note the significant trends and policy recommendations for the healthy integration of AI in education.

6   Future prospects and conclusions

Today, GAI is pushing the boundaries of education and has already personalised learning, automated content creation, and improved assessments. As AI models become more sophisticated and find their way into our education system, there will be new opportunities and challenges to what and how we include them in our education systems. Technological innovations, policy developments, and ethical considerations shape the future of AI-driven education and define how much AI can enhance the learning experience. AI in education is expected to be applied beyond traditional learning environments, including virtual reality (VR), augmented reality (AR), real-time AI-assisted mentoring, and fully adaptive AI-driven curricula. With the amount of educational data that AI is learning, its ability to customise learning materials, predict student performance, and increase teacher productivity will see dramatic improvements. However, the success of AI-driven education would depend on ethical issues, i.e., data privacy and the balance of AI and human educators. In this section, the emerging trends, potential applications and challenges to be mitigated that will define the future of AI-powered education. It concludes with a comprehensive conclusion detailing the significant insights concerning this study and calls attention to adopting a responsible AI environment for learning.

6.1   Emerging trends in AI-driven education

Two key trends that will shape the future of AI in education are more personalised learning experiences and increasing accessibility with a wide variety of AI-powered tools in digital classrooms. The overview of the anticipated progress in AI-driven education and its likely effect is given in Table 12.

It shows that AI will be a tool for personal education and work as a part of the learning ecosystem. As well-developed AI-powered educational platforms evolve, more interactive, accessible, and student-focused learning experiences will be created.

6.2   Challenges in implementing future AI-driven education

The promising areas of AI-driven education must also address some challenges to make it fair, ethical, and purposeful. With data security, the growing reliance on AI means that the most significant issues to be concerned with are bias in the AI-generated content, teacher displacement, and the possibility of excessive over-dependency on AI-driven learning systems. Bias is one of the significant concerns of AI since the datasets on which their models are trained are entirely culturally gender or socioeconomic-biased. Lacking the proper control, AI-built educational materials could perpetuate existing inequalities and unequal learning possibilities. Moreover, data privacy and security are equally crucial as AI-based learning platforms collect much information about student performance and personal preferences. Data encryption must be in place to protect student information, and transparent policies and strict adherence to educational

regulations must be in place. A key place challenge is the possibility of human educators being displaced. AI can augment teaching efficiency, but it cannot replaced by AI in helping cultivate creativity, critical thinking and emotional intelligence. AI-driven education's future will be to tie AI with human instructors for collaboration, and AI will be an assistive tool rather than a replacement for traditional educational methods – Table 13 lists significant challenges in developing future AI-enabled education and how these challenges can be overcome.

Table 12 Future trends in AI-driven education

Future trend	Description	Expected impact
AI-powered virtual tutors	AI-driven real-time tutoring systems that provide instant assistance and personalised learning support	Increased student engagement, improved comprehension, and reduced need for traditional tutoring
AI-generated adaptive curricula	AI systems that dynamically adjust course content based on individual student progress	Fully customised learning experiences that cater to diverse learning styles
AI and VR/AR integration	Combining AI with immersive technologies like virtual reality (VR) and augmented reality (AR) to create interactive learning experiences	Enhanced engagement through hands-on, experiential learning in digital environments
Emotion AI in education	AI analyses student emotions and engagement levels to tailor teaching strategies accordingly	Improved student well-being, reduced learning stress, and optimised classroom interactions
AI for early learning interventions	AI predicts learning difficulties and provides targeted interventions for struggling students	Reduced dropout rates and enhanced student success in academic performance

Table 13 Challenges and solutions in AI-driven education

| Challenge	Description	Potential solutions
AI bias in content generation	AI may produce biased educational materials, reinforcing stereotypes	Developing diverse and representative training datasets; implementing bias detection algorithms
Data privacy and security	AI-driven platforms require access to student data, raising privacy concerns	Enforcing strict data encryption policies, ensuring compliance with privacy regulations (e.g., GDPR, FERPA)
Over-reliance on AI	Students may become too dependent on AI-generated responses, reducing critical thinking skills	Encouraging a balanced approach to AI use, integrating AI as a supplementary tool rather than a primary learning method
Educator displacement	AI automation may reduce the demand for human instructors	Training teachers to use AI effectively, redefining teaching roles to focus on mentorship and creativity

Addressing these challenges will ensure AI is implemented ethically and responsibly in future educational systems.

6.3 Conclusions

GAI transforms education by integrating AI-powered tutoring systems and a new generation of immersive education tools. Some real-world implementations of AI-driven education show its ability to increase engagement, automate content creation, and

improve assessment methods, as implemented in Khan Academy, Duolingo, and AI providers such as those for plagiarism detection. AI-driven education has gone from static learning management systems to dynamic adaptive AI-powered learning experiences. The one that has helped educate our society with continued inclusivity and accessibility is AI. However, ethical concerns and implementation challenges related to AI adoption in education must be addressed efficiently. These top trends will form the basis for how AI will shape the future of education: AI-powered virtual tutors, immersive VR/AR integration and AI-driven emotional analysis in classrooms. With these advancements, student engagement will be further increased, and more adaptive and real-time learning experiences will be made possible. Despite this, there are significant issues around bias in AI-generated content, data privacy risks, reliance on AI tools and teacher displacement, which must be handled carefully. Figure 9 shows the ideal AI operationalised education model, in which human educators complement AI to work together to build the optimal learning ecosystem.

Figure 9   AI-human collaborative learning model (see online version for colours)
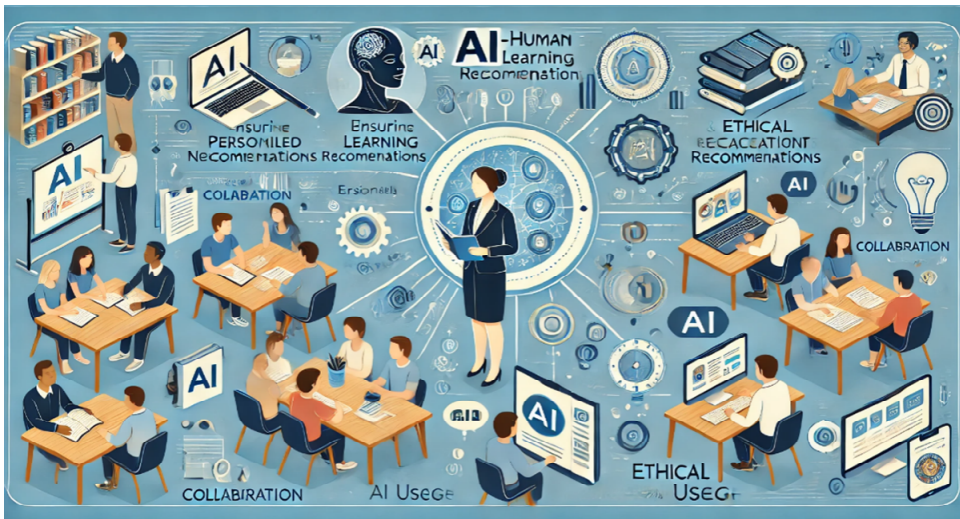
To harness the power of AI-driven education to the most, policymakers, educators, and AI developers must come together to set ethical guiding principles, data protection frameworks and AI bias mitigation strategies. To ensure the successful future of AI in education, it will matter to ensure that AI is a tool for empowerment, not a replacement for human-led education. Educators have discovered that AI-driven education can bridge the learning gap, making education more accessible and engaging. However, AI should be responsible for implementation and continuous oversight as it should not replace traditional educational values but be a complementary force that helps humans learn. This study's findings demonstrate the transformative potential of AI in education and the significance of the ethical adoption of AI. Future research should optimise AI-human collaboration in learning environments to ensure that AI works to enhance creativity, critical thinking, and moral learning practices. There will be a further evolution of AI-driven education. Still, if brought in the right way, it will become more inclusive, efficient, and equitable in providing education to students worldwide.

Funding

Declarations

The authors of this study declare that they have no conflict of interest.

Notes

An earlier version of this article contained some minor inaccuracies which have been corrected as follows:

Page 102: In the original published version of this article, the gender of the second author, Fang Sun, was incorrectly stated as female. This has been corrected to male.

Page 116:4.4 In the original published version of this article, the word 'στηควบค�â' appeared in error. It should be 'undermine'. This has been corrected. The authors regret the mistake.

Page 122: In the original published version of this article, the figure following Figure 8 was incorrectly labelled as Figure 10. It should be Figure 9. This has been corrected.

References

Al Nabhani, F., Hamzah, M. and Abuhassna, H. (2025) 'The role of artificial intelligence in personalizing educational content: enhancing the learning experience and developing the teacher's role in an integrated educational environment', *Contemporary Educational Technology*, Vol. 17, No. 2, pp.90–113.

Alasadi, E.A. and Baiz, C.R. (2023) 'Generative AI in education and research: opportunities, concerns, and solutions', *Journal of Chemical Education*, Vol. 100, No. 8, pp.2965–2971.

Ali, M., Siddique, A., Aftab, A., Abid, M.K. and Fuzail, M. (2024) 'AI-powered customized learning paths: transforming data administration for students on digital platforms', *Journal of Computing & Biomedical Informatics*, Vol. 6, No. 2, pp.195–204.

Almuhanna, M.A. (2024) 'Teachers' perspectives of integrating AI-powered technologies in K-12 education for creating customized learning materials and resources', *Education and Information Technologies*, Vol. 29, No. 13, pp.1–29.

Almusaed, A., Almssad, A., Yitmen, I. and Homod, R.Z. (2023) 'Enhancing student engagement: harnessing 'AIED's' power in hybrid education – a review analysis', *Education Sciences*, Vol. 13, No. 7, p.632.

Annepaka, Y. and Pakray, P. (2024) 'Large language models: a survey of their development, capabilities, and applications', *Knowledge and Information Systems*, Vol. 67, No. 3, pp.1–56.

Arya, R. and Verma, A. (2024) 'Role of artificial intelligence in education', *International Journal of Advanced Research in Science, Communication and Technology*, Vol. 4, No. 2, pp.589–594.

Attard, A. and Dingli, A. (2024) 'Empowering educators: leveraging large language models to streamline content creation in education', *ICERI2024 Proceedings*, IATED, pp.1312–1321.

Awidi, I.T. (2024) 'Comparing expert tutor evaluation of reflective essays with marking by generative artificial intelligence (AI) tool', *Computers and Education: Artificial Intelligence*, Vol. 6, p.100226.

Banjade, S., Patel, H. and Pokhrel, S. (2024) 'Empowering education by developing and evaluating generative AI-powered tutoring system for enhanced student learning', *Journal of Artificial Intelligence and Capsule Networks*, Vol. 6, No. 3, pp.278–298.

Berking, P. and Gallagher, S. (2013) 'Choosing a learning management system', *Advanced Distributed Learning (ADL) Co-Laboratories*, Vol. 14, No. 4, pp.40–62.

Borger, J.G., Ng, A.P., Anderton, H., Ashdown, G.W., Auld, M., Blewitt, M.E., Brown, D.V., Call, M.J., Collins, P. and Freytag, S. (2023) 'Artificial intelligence takes center stage: exploring the capabilities and implications of ChatGPT and other AI-assisted technologies in scientific research and education', *Immunology and Cell Biology*, Vol. 101, No. 10, pp.923–935.

Campino, J. (2024) 'Unleashing the transformers: NLP models detect AI writing in education', *Journal of Computers in Education*, Vol. 15, No. 9, pp.1–29.

Chakraborty, S. (2024) *Generative AI in Modern Education Society*, arXiv preprint arXiv:2412. 08666.

Chakraborty, S., Misra, B. and Dey, N. (2024) *AI-Empowered Knowledge Management in Education*, Vol. 4, No. 1, pp.70–90, Springer.

Chen, L., Chen, P. and Lin, Z. (2020) 'Artificial intelligence in education: a review', *IEEE Access*, Vol. 8, pp.75264–75278.

Chen, Y., Jensen, S., Albert, L.J., Gupta, S. and Lee, T. (2023) 'Artificial intelligence (AI) student assistants in the classroom: designing chatbots to support student success', *Information Systems Frontiers*, Vol. 25, No. 1, pp.161–182.

Cheng, Y., Fan, Y., Li, X., Chen, G., Gašević, D. and Swiecki, Z. (2025) 'Asking generative artificial intelligence the right questions improves writing performance', *Computers and Education: Artificial Intelligence*, p.100374.

Chiu, T.K. (2024) *Empowering K-12 Education with AI: Preparing for the Future of Education and Work*, Vol. 7, No. 5, pp.87–100, Taylor & Francis.

Dimitrov, T., Kreisbeck, C., Becker, J.S., Aspuru-Guzik, A. and Saikin, S.K. (2019) 'Autonomous molecular design: then and now', *ACS Applied Materials & Interfaces*, Vol. 11, No. 28, pp.24825–24836.

Ebbini, E. (2023) 'Enhancing collaborative and self-paced learning in traditional and distance education settings', *Higher Education in the Arab World: E-learning and Distance Education*, Vol. 10, No. 3, pp.223–245, Springer.

Elmourabit, Z., Retbi, A. and El Faddouli, N-E. (2024) 'The impact of generative artificial intelligence on education: a comparative study', *Proceedings of the 23rd European Conference on E-Learning*, Academic Conferences International.

Fan, L., Kim, J., Detrick, R. and Li, N. (2025) *Developing Students' Higher-Order Thinking Skills With Generative AI Insights and Strategies From a Case Study. Prompt Engineering and Generative AI Applications for Teaching and Learning*, Vol. 87, No. 45, pp.411–428, IGI Global Scientific Publishing.

Forrester, A., Sobester, A. and Keane, A. (2008) *Engineering Design via Surrogate Modelling: A Practical Guide*, John Wiley & Sons.

George, A.S. (2023) 'Preparing students for an AI-driven world: rethinking curriculum and pedagogy in the age of artificial intelligence', *Partners Universal Innovative Research Publication*, Vol. 1, No. 2, pp.112–136.

Giri, A. (2025) *Revolutionizing Student Evaluation: The Power of AI-Powered Assessment. Improving Student Assessment with Emerging AI Tools*, pp.333–362, IGI Global Scientific Publishing.

Gm, D., Goudar, R., Kulkarni, A.A., Rathod, V.N. and Hukkeri, G.S. (2024) 'A digital recommendation system for personalized learning to enhance online education: a review', *IEEE Access*, Vol. 12, pp.34019–34041.

Godwin-Jones, R. (2024) *Distributed Agency in Second Language Learning and Teaching Through Generative AI*, arXiv preprint arXiv:2403.20216.

Gonsalves, C. (2024) 'Generative AI's impact on critical thinking: revisiting Bloom's taxonomy', *Journal of Marketing Education*, Vol. 60, No. 15, p.2734753241305980.

Hadi, M.U., Al-Tashi, Q., Qureshi, R., Shah, A., Muneer, A., Irfan, M., Zafar, A., Shaikh, M.B., Akhtar, N. and Al-Garadi, M.A. (2025) *LLMs: A Comprehensive Survey of Applications, Challenges, Datasets, Models, Limitations, and Future Prospects*, pp.439–464, DOI: 10.4018/979-8-3693-9311-6.ch012.

Hadi, M.U., Qureshi, R., Shah, A., Irfan, M., Zafar, A., Shaikh, M.B., Akhtar, N., Wu, J. and Mirjalili, S. (2023) 'Large language models: a comprehensive survey of its applications, challenges, limitations, and future prospects', *Authorea Preprints*, Vol. 1, No. 3, pp.1–26.

Hong, Y., Wu, J., Wu, J., Xu, H., Li, X., Lin, Z. and Xia, J. (2023) 'Semi-flipped classroom-based learning interventions in a traditional curriculum of oral medicine: students' perceptions and teaching achievements', *BMC Medical Education*, Vol. 23, No. 1, p.44.

Hooda, M., Rana, C., Dahiya, O., Rizwan, A. and Hossain, M.S. (2022) 'Artificial intelligence for assessment and feedback to enhance student success in higher education', *Mathematical Problems in Engineering*, Vol. 2022, No. 1, p.5215722.

Kar, A.K., Varsha, P. and Rajan, S. (2023) 'Unravelling the impact of generative artificial intelligence (GAI) in industrial applications: a review of scientific and grey literature', *Global Journal of Flexible Systems Management*, Vol. 24, No. 4, pp.659–689.

Kavitha, R., Krupa, C.R. and Kaarthiekheyan, V. (2023) 'AI-powered digital solutions for smart learning: revolutionizing education', *Cybersecurity and Data Science Innovations for Sustainable Development of HEICC*, Vol. 6, No. 2, pp.213–227, CRC Press.

Khosravi, H., Denny, P., Moore, S. and Stamper, J. (2023) 'Learner sourcing in the age of AI: student, educator and machine partnerships for content creation', *Computers and Education: Artificial Intelligence*, Vol. 5, No. 3, p.100151.

Khosravi, H., Shum, S.B., Chen, G., Conati, C., Tsai, Y-S., Kay, J., Knight, S., Martinez-Maldonado, R., Sadiq, S. and Gašević, D. (2022) 'Explainable artificial intelligence in education', *Computers and Education: Artificial Intelligence*, Vol. 3, No. 1, p.100074.

Kumar, T., Kait, R., Ankita and Malik, A. (2023) 'The role of generative artificial intelligence (GAI) in education: a detailed review for enhanced learning experiences', *International Conference on Entrepreneurship, Innovation, and Leadership*, pp.195–207, Springer.

Liu, M., Ren, Y., Nyagoga, L.M., Stonier, F., Wu, Z. and 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*, Vol. 1, No. 1, pp.72–101.

Lu, C. and Cutumisu, M. (2021) *Integrating Deep Learning into an Automated Feedback Generation System for Automated Essay Scoring*, International Educational Data Mining Society.

Luckin, R. and Holmes, W. (2016) 'Intelligence unleashed: an argument for AI in education'.

Macgilchrist, F., Allert, H. and Bruch, A. (2020) 'Students and society in the 2020s. Three future' histories' of education and technology', *Learning, Media and Technology*, Vol. 45, No. 1, pp.76–89.

Madavan, K.T. (2022) 'Effectiveness and perception of demonstration-observation-assistance-performance (DOAP) versus video-assisted learning (VAL) in training advanced cardiac life support (ACLS) among medical interns – a comparative study', *Journal of Education and Health Promotion*, Vol. 11, No. 1, p.412.

Makinde, A.I., Adeleye, S.A., Oronti, A.O. and Jimoh, I.T. (2024) 'Revolutionizing education', *Artificial Intelligence for Wireless Communication Systems: Technology and Applications*, Vol. 103, No. 12, pp.244–269.

Mammadova, T. (2023) *Academic Writing and Information Literacy Instruction in Digital Environments: A Complementary Approach*, Vol. 9, No. 6, pp.112–125, Springer Nature.

Marengo, A. and Pange, P.J. (2024) 'Envisioning general AI in higher education: transforming learning paradigms', *Creative Approaches to Technology-Enhanced Learning for the Workplace and Higher Education: Proceedings of 'The Learning Ideas Conference' 2024*, Springer Nature, Vol. 1, pp.330–344.

Mittal, U., Sai, S. and Chamola, V. (2024) 'A comprehensive review on generative AI for education', *IEEE Access*, Vol. 12, pp.142733–142759.

Moreira, F.T. and Teles, R.O. (2024) *Improving Student Assessment with Emerging AI Tools*, IGI Global, UK.

Murphy, R.F. (2019) 'Artificial intelligence applications to support K-12 teachers and teaching', *Rand Corporation*, Vol. 10, No. 1, pp.1–20.

Paiva, J.C., Leal, J.P. and Figueira, Á. (2022) 'Automated assessment in computer science education: a state-of-the-art review', *ACM Transactions on Computing Education (TOCE)*, Vol. 22, No. 3, pp.1–40.

Paiz, J.M., Toncelli, R. and Kostka, I. (2025) *Artificial Intelligence, Real Teaching: A Guide to AI in ELT*, University of Michigan Press, USA.

Pang, W. and Wei, Z. (2025) 'Shaping the future of higher education: a technology usage study on generative AI innovations', *Information*, Vol. 16, No. 2, p.95.

Panke, S. (2024) 'Open educational resources and artificial intelligence for future open education', *Mousaion*, Vol. 42, No. 1, pp.213–227.

Pratschke, B.M. (2024) *Generative AI and Education: Digital Pedagogies, Teaching Innovation and Learning Design*, Vol. 25, No. 5, Springer.

Qadir, J. (2025) *Generative AI in Undergraduate Classrooms: Lessons from Implementing a Customized GPT Chatbot for Learning Enhancement*, Authorea Preprints, USA.

Raiaan, M.A.K., Mukta, M.S.H., Fatema, K., Fahad, N.M., Sakib, S., Mim, M.M.J., Ahmad, J., Ali, M.E. and Azam, S. (2024) 'A review on large language models: architectures, applications, taxonomies, open issues and challenges', *IEEE Access*, Vol. 12, No. 4, pp.26839–26874.

Relan, A. and Gillani, B.B. (1997) 'Web-based instruction and the traditional classroom: similarities and differences', *Web-based Instruction*, Vol. 62, pp.41–46.

Roscoe, R.D. and Craig, S.D. (2022) 'A heuristic assessment framework for the design of self-regulated learning technologies', *Journal of Formative Design in Learning*, Vol. 6, No. 2, pp.77–94.

Ruiz-Rojas, L.I., Salvador-Ullauri, L. and Acosta-Vargas, P. (2024) 'Collaborative working and critical thinking: adoption of generative artificial intelligence tools in higher education', *Sustainability*, Vol. 16, No. 13, p.5367.

Saini, A.K., Cope, B., Kalantzis, M. and Zapata, G.C. (2024) *The Future of Feedback: Integrating Peer and Generative AI Reviews to Support Student Work*, Vol. 10.

Sandhu, R., Channi, H.K., Ghai, D., Cheema, G.S. and Kaur, M. (2024) 'An introduction to generative AI tools for education 2030', *Integrating Generative AI in Education to Achieve Sustainable Development Goals*, Vol. 8, No. 4, pp.1–28.

Singh, T.M., Reddy, C.K.K., Murthy, B.R., Nag, A. and Doss, S. (2025) 'AI and education: bridging the gap to personalized, efficient, and accessible learning', *Internet of Behavior-based Computational Intelligence for Smart Education Systems*, Vol. 9, No. 3, pp.131–160, IGI Global.

Slattery, M. (2024) *Education Strategy in a Changing Society: Personalized, Smarter, Lifelong Learning in the 21st Century*, Vol. 2, No. 1, pp.80–101, Taylor & Francis.

Sridharan, R., Sukanya, N. and Sivasakthi, B. (2024a) 'Machine learning/deep learning', *Artificial Intelligence based Solutions for Industrial Applications*, Vol. 12, No. 8, p.124.

Sridharan, R., Sukanya, N., Sivasakthi, B. and Sankaran, V. (2024b) 'Machine learning/deep learning use cases in education', *Artificial Intelligence based Solutions for Industrial Applications*, Vol. 7, No. 1, pp.124–148, CRC Press.

Srinivasa, K., Kurni, M. and Saritha, K. (2022) 'Harnessing the power of AI to education', *Learning, Teaching, and Assessment Methods for Contemporary Learners: Pedagogy for the Digital Generation*, Vol. 7, No. 2, pp.311–342, Springer.

Sundari, M.S., Penthala, H.R. and Nayyar, A. (2022) 'Transforming education through AI-enhanced content creation and personalized learning experiences', *Impact of Artificial Intelligence on Society*, Chapman and Hall/CRC.

Suresh, C., Ali, S.M. and Devaki, V. (2025) 'Perception about usage of GAI tools in teaching and research by teachers and students in higher education institutions', *Impacts of AI on Students and Teachers in Education 5.0*, Vol. 3, No.1 , pp.381–412, IGI Global Scientific Publishing.

Tanweer, M. and Ismail, A. (2024) 'Generative AI in curriculum development: a framework for adaptive, customized, and personalized learning', *Impacts of Generative AI on Creativity in Higher Education*, Vol. 8, No. 4, pp.193–226, IGI Global.

Tila, D. and Levy, D. (2023) 'Curating OER content through AI and ChatGPT', *Open Journal of Social Sciences*, Vol. 11, No. 12, pp.510–527.

Turnbull, D., Chugh, R. and Luck, J. (2020) 'Learning management systems, an overview', *Encyclopedia of Education and Information Technologies*, Vol. 9, No. 6, pp.1052–1058.

Walker, D.F. and Schaffarzick, J. (1974) 'Comparing curricula', *Review of Educational Research*, Vol. 44, No. 1, pp.83–111.

Williamson, B. and Eynon, R. (2020) *Historical Threads, Missing Links, and Future Directions in AI in Education*, Vol. 45, No. 7, pp.223–235, Taylor & Francis.

Woolf, B.P. (2010) *Building Intelligent Interactive Tutors: Student-Centered Strategies for Revolutionizing E-Learning*, Morgan Kaufmann.

Yadav, S. (2025) 'Leveraging AI to enhance teaching and learning in education: the role of artificial intelligence in modernizing classroom practices', *Optimizing Research Techniques and Learning Strategies with Digital Technologies*, Vol. 8, No. 2, pp.211–238, IGI Global Scientific Publishing.

Yam, K.L. (2010) *The Wiley Encyclopedia of Packaging Technology*, John Wiley & Sons.

Yan, L., Greiff, S., Teuber, Z. and Gašević, D. (2024a) 'Promises and challenges of generative artificial intelligence for human learning', *Nature Human Behaviour*, Vol. 8, No. 10, pp.1839–1850.

Yan, L., Martinez-Maldonado, R. and Gasevic, D. (2024b) 'Generative artificial intelligence in learning analytics: contextualizing opportunities and challenges through the learning analytics cycle', *Proceedings of the 14th Learning Analytics and Knowledge Conference*, pp.101–111.

Yu, H. and Guo, Y. (2023) 'Generative artificial intelligence empowers educational reform: current status, issues, and prospects', *Frontiers in Education*, Vol. 8, No. 3, p.1183162, Frontiers Media SA.

Zhai, X., Chu, X., Chai, C.S., Jong, M.S.Y., Istenic, A., Spector, M., Liu, J-B., Yuan, J. and Li, Y. (2021) 'A review of artificial intelligence (AI) in education from 2010 to 2020', *Complexity*, Vol. 2021, No. 1, p.8812542.

Zhai, X., Nyaaba, M. and Ma, W. (2024) 'Can generative AI and ChatGPT outperform humans on cognitive-demanding problem-solving tasks in science?', *Science & Education*, pp.1–22.