

Research on the Application of Generative Artificial Intelligence in Education

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Abstract: Generative artificial intelligence (AI), equipped with capabilities such as large language models, multimodal generation, and adaptive interaction, is deeply penetrating the education sector and driving reforms in teaching models, learning methods, and teaching evaluation systems. Adopting a collaborative analytical framework of technology, education, and ethics, this paper sorts out the technical characteristics and educational applicability of generative AI, and constructs a full-scenario application system covering basic education, higher education, and vocational education. Combined with typical cases, it reveals its application value in personalized learning, human-machine collaborative teaching, intelligent evaluation and feedback, and balanced allocation of educational resources. The study finds that generative AI can improve teaching efficiency, optimize learning experience, and promote educational equity, but it also faces multiple challenges including technical hallucinations, data security, ethical anomalies, digital divide, and academic integrity. Accordingly, this paper proposes a development path of controllable technology, education-oriented, ethics-guarded, and collaborative governance, and builds an integrated application ecosystem featuring policy regulation, technical optimization, literacy improvement, and scenario innovation, so as to provide theoretical support for the safe, standardized, and efficient implementation of generative AI in education.

Keywords: Generative artificial intelligence; Digitization of education; Personalized learning; Human-machine collaboration; Educational ethics

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1. Introduction

The world has entered the era of Artificial Intelligence 2.0. Represented by large language models, diffusion models, and multi-modal generation technologies, generative artificial intelligence (AI) has achieved a leap from “understanding data” to “creating content,” becoming a core technology driving the digital economy and social transformation^[1]. In 2023, UNESCO issued the *Guidelines for Generative AI in Education and Research*, clearly positioning generative AI as a key driver of educational transformation. Policy documents in China, such as the *Outline for the Construction of a Strong Educational Country (2024–2035)* and

the *Action Plan for Promoting High-Quality Development of Basic Education Empowered by Artificial Intelligence (2024–2026)*, have proposed the deployment of the “Artificial Intelligence + Education” strategy to promote the deep integration of generative AI into education and teaching.

As a key area of digital transformation, education is confronted with numerous challenges, including insufficient supply of high-quality resources, difficulties in implementing personalized instruction, excessive teaching burdens on educators, and simplistic evaluation methods^[2]. Generative AI, with its capabilities in content generation, interactive dialogue, logical reasoning, and adaptive matching, provides technical solutions to address the dilemmas of traditional education^[3–5]. From intelligent lesson preparation and virtual teaching assistants to personalized learning pathways, and from automated assessment and academic progress analysis to cross-regional provision of educational resources, generative AI is reshaping the entire process of education and teaching. It is driving the transformation of education from “standardized” to “personalized,” from “knowledge transmission” to “competency development,” and from “teacher-led” to “human-machine collaborative” models^[6,7]. The emergence of generative artificial intelligence tools such as ChatGPT, DeepSeek, Claude, and QuillBot has significantly transformed the landscape of higher education^[8–10]. While these tools offer innovative opportunities for teaching and learning, they also pose severe challenges for instructors seeking to assess student performance meaningfully and ethically^[11–13]. By 2025, over 86% of students worldwide had used generative AI to support their learning. In China, cities including Shanghai and Beijing have taken the lead in launching domain-specific large language models for education, marking the entry of generative AI applications in education into a stage of large-scale exploration.

The OECD has released *Digital Education Outlook 2026*, proposing a human-machine collaboration framework of “substitution–complementation–augmentation” and clarifying a layered application path for technology. UNESCO, the European Union, and other organizations have established ethical review and data security regulations to strengthen the controllability of technology in educational scenarios^[14]. The Chinese Society of Education has issued the *Guidelines for the Use of Generative Artificial Intelligence in Primary and Secondary Schools (2025 Edition)*, constructing application norms by school stage and scenario. Cities such as Shanghai and Shenzhen have formed localized practical cases through pilot projects based on large educational models. However, overall shortcomings still exist, including insufficient systematic research, a lack of empirical data, and an imperfect governance system, making it urgent to establish a comprehensive research framework.

This study aims to clarify the internal logic of the integration between generative artificial intelligence and education, construct a theoretical framework featuring technology education ethics coordination, and enrich the theoretical system of intelligent education and educational digitalization. By systematically defining the application boundaries and value positioning of generative AI in the education sector, it addresses the shortcomings of existing research that overemphasizes technology over ethics and application over governance. Furthermore, based on application analyses across all educational stages and scenarios, this study proposes feasible implementation paths and risk prevention and control strategies, facilitating generative AI to empower educational equity, promote the delivery of high-quality educational resources to underdeveloped areas, and continuously improve teaching efficiency and learning quality.

2. Generative artificial intelligence technology

Generative artificial intelligence is a type of AI technology based on deep learning, large language

models, multimodal interaction, and other techniques, which can independently generate content including text, images, audio, video, and code. It consists of four core modules: large language models (LLMs), retrieval-augmented generation (RAG), multimodal generation, and intelligent interaction. Compared with traditional discriminative AI, generative AI has core characteristics of content creativity, natural interaction, logical reasoning, and personalized adaptation, realizing an upgrade from “tool assistance” to “partner collaboration.”

Generative AI supports cross-modal content generation covering text, images, audio, video, and virtual scenes, which can meet the diverse resource demands in educational scenarios. It enables human-like dialogue and Socratic questioning, overcoming the mechanical limitations of traditional human-computer interaction. With capabilities in knowledge summarization, logical deduction, and interdisciplinary integration, it provides support for the cultivation of higher-order thinking. It can dynamically adjust content based on user behavior data to achieve personalized adaptation tailored to individual differences. Furthermore, it can update content in real time and keep pace with disciplinary frontiers through continuous learning, ensuring the timeliness of teaching content.

By analyzing the technical characteristics of generative AI, it can be found that it highly matches the essential needs of education and can form a synergistic effect of technology empowerment and education quality improvement. The adaptability analysis is shown in **Table 1**.

Table 1. Adaptability between technical characteristics of generative AI and educational needs

Technical characteristics	Educational needs	Adaptive value
Multi-modal Generation	Diverse teaching resources, immersive learning scenarios	Automatically generates lesson plans, courseware, and virtual experiments, enriching teaching forms
Natural Language Interaction	Personalized Q&A, interactive learning	Builds intelligent learning companions and virtual teaching assistants for real-time interactive tutoring
Logical Reasoning	Cultivation of higher-order thinking and innovative abilities	Guides inquiry-based learning and supports the improvement of critical thinking and problem-solving skills
Adaptive Adaptation	Personalized learning, teaching students in accordance with their aptitude	Dynamically matches learning paths and hierarchical tasks, solving the dilemma of standardized teaching
Real-time Iteration	Knowledge updating, frontier-oriented teaching	Synchronizes the latest disciplinary achievements to meet lifelong learning needs
Data Processing	Learning status analysis, precise evaluation	Mines learning data to realize process-based evaluation and personalized feedback

2.1. Application status

At present, generative AI has penetrated the entire process of education and teaching, including instruction, learning, and assessment, covering all educational stages from basic education and higher education to vocational education, forming a full-process, full-scenario application ecosystem.

In teaching, generative AI can automatically generate lesson plans, courseware, exercises, and teaching activity plans based on teaching objectives and learning situation data, helping teachers focus on teaching optimization and innovation. It also supports interdisciplinary integrated design, adapting to project-based, inquiry-based, and other new teaching models^[15]. Relying on AR/VR technology to create virtual scenarios, it reconstructs historical scenes, visualizes microscopic principles, and conducts virtual science experiments. Combined with intelligent interactive tools, teachers can grasp learning status in real time and flexibly adjust teaching pace, constructing a smart classroom that adapts teaching to learning. In addition, AI virtual teaching

assistants can handle after-class tasks such as homework Q&A, knowledge explanation, and study reminders, effectively reducing teachers' workload. Their multilingual and multi-dialect interactive capabilities also better serve students in remote areas and those with special needs.

In terms of learning, artificial intelligence can dynamically customize exclusive learning plans based on learners' knowledge graphs, learning habits, and cognitive levels, accurately push hierarchical learning resources and targeted exercises, and realize teaching students in accordance with their aptitude on a large scale. Through Socratic questioning, it guides students to carry out interactive inquiry learning, supports interdisciplinary research, creative output, and simulation deduction, and cultivates innovative thinking and problem-solving abilities. At the same time, it can provide barrier-free learning services, such as producing audio textbooks, sign language animations, and tactile models for visually and hearing-impaired students. It can also provide basic tutoring and repeated explanations for students with learning difficulties, reduce learning barriers, and promote the realization of educational equity.

In terms of teaching evaluation, artificial intelligence can automatically grade compositions, programming tasks, and subjective questions while generating detailed diagnostic reports, greatly improving feedback efficiency by 90%. It also records learning trajectories and thinking processes throughout to conduct process-based evaluation, making up for the deficiencies of traditional summative assessment. Its evaluation dimensions are no longer limited to scores; it can comprehensively assess core competencies such as creativity, critical thinking, and collaboration skills, and construct learner ability profiles based on data to provide references for teaching optimization. In addition, the system can customize personalized test questions and open-ended tasks to avoid mechanical repetitive practice, and use algorithm optimization to reduce evaluation bias, effectively ensuring the fairness of evaluation.

In different teaching stages, the application of generative AI should be guided hierarchically and categorically according to the cognitive laws of each stage. The detailed analysis is shown in **Table 2**.

Table 2. Application scenarios and boundaries of generative AI by educational stage

Education stage	Core application scenarios	Usage boundaries	Key values
Basic Education	Intelligent lesson preparation, virtual teaching assistants, interactive learning, resource generation	Independent use of open generative functions is prohibited for primary school students; junior secondary focuses on logical analysis; senior secondary supports inquiry-based learning	Inspire interest, consolidate foundations, develop learning habits
Higher Education	Research assistance, thesis guidance, professional teaching, innovative practice	Regulate academic integrity, support scientific innovation and in-depth learning	Higher-order thinking, research competence, innovation literacy
Vocational Education	Virtual training, skill tutoring, job simulation, career planning	Align with industrial needs, strengthen practical operation training	Skill improvement, professional literacy, employment adaptability

2.2. Practical challenges

The application of generative artificial intelligence in education features both empowering value and potential risks, facing challenges in four dimensions: technology, ethics, education, and equity.

At the technical level, generative AI is prone to hallucinations and distortions such as factual errors and logical biases, which can easily mislead primary and secondary school students with immature cognitive abilities. Meanwhile, the black-box nature of algorithms leads to a lack of transparency in decision-

making logic, making evaluation results and learning recommendations difficult to trace, thus undermining educational equity and public trust. In addition, stability defects such as system freezes, data delays, and poor adaptability can disrupt normal teaching rhythms.

At the ethical level, educational scenarios collect a large amount of sensitive data, including students' personal information, learning trajectories, and family data, facing privacy and security risks of information leakage and abuse. Some students use artificial intelligence to ghostwrite homework, papers, and even cheat in examinations, giving rise to academic integrity issues that violate the original intention of learning and academic norms. Content generated by models may contain cognitive and value biases, which are not conducive to the formation of correct values among adolescents. In addition, such content is prone to copyright infringement, making it difficult to effectively protect intellectual property rights.

In terms of education, excessive use of artificial intelligence by teachers and students tends to cause cognitive inertia, which may gradually weaken students' independent thinking, memory, and innovation abilities, leading to superficial learning. Some teachers suffer from professional anxiety about being replaced by technology, while their ability to apply intelligent technology and design new teaching models struggles to adapt to the new forms of instruction. Excessive intervention of technology may also dilute emotional communication and humanistic care between teachers and students, giving rise to a tendency to emphasize technology over moral education, thus deviating from the fundamental goal of fostering virtue through education.

In terms of equity, gaps between urban and rural areas, regions, and schools in hardware facilities, teacher quality, and digital resources will further widen the digital divide and give rise to new forms of educational inequity. Current relevant policies, regulations, ethical guidelines, and supervision mechanisms lag behind technological development; unified access standards, evaluation systems, and accountability mechanisms have not yet been established, resulting in obvious shortcomings in the governance system. Families, schools, and society hold inconsistent understandings of the educational application of artificial intelligence and lack effective supervision, making it impossible to form a collaborative governance framework among family, school, and society.

3. Development paths and countermeasures

Faced with multiple challenges exposed in the educational application of generative AI, including technical limitations, ethical risks, educational alienation, and unfair imbalances, this paper adheres to the principles of “empowerment by technology without overstepping boundaries, education-oriented with original aspiration upheld, ethics as a guarantee to build the bottom line, and collaborative governance for long-term effectiveness.” It proposes constructing a coordinated development ecosystem integrating policy regulation, technical optimization, literacy improvement, and scenario innovation, which can systematically resolve pain points arising from the application of AI technology in education and promote the in-depth, healthy, and sustainable integration of generative AI into teaching and learning.

3.1. Policy regulation: Improve top-level design and perfect the governance system

Focusing on institutional development, a full-chain governance framework covering access, application, evaluation, and accountability shall be established. First, improve the standard and normative system by issuing special policies for generative AI in the education sector, clarifying requirements for access

qualifications, data compliance, content review, and ethical norms, implementing a “white list” system for educational AI tools, and strictly controlling the entry threshold of technology into schools. Second, build a diversified collaborative governance pattern, forming a governance mechanism featuring “overall supervision by the government, primary responsibility by schools, technical support by enterprises, empowerment by research institutions as think tanks, and collaborative supervision by families and society,” with clear rights and responsibilities to form joint forces. Third, establish a dynamic evaluation and iteration mechanism to regularly monitor the application effects of educational AI, and continuously optimize policy standards and ethical norms based on practical feedback to ensure that institutions adapt to technological development and educational needs.

3.2. Technical optimization: Break through core bottlenecks and achieve controllable empowerment

Focus on technological shortcomings, promote the iterative upgrading of education-specific technologies, and build a secure and controllable technological foundation. First, develop large language models dedicated to education, optimize training data around knowledge rigor and value orientation, filter erroneous information and biased content, strengthen knowledge accuracy, logical rigor, and educational adaptability, and reduce technical hallucinations at the source. Second, enhance retrieval augmentation and traceability auditing, deeply apply Retrieval-Augmented Generation (RAG) technology, connect with authoritative educational knowledge bases, and realize real-time content verification and traceability; improve the algorithm transparency mechanism to ensure interpretable and traceable evaluation and recommendation results. Third, improve system stability and security, optimize the technical architecture to solve problems such as freezes, delays, and insufficient adaptation; establish a full-process content review, risk early warning, and harmful information interception mechanism to ensure safe, stable, and efficient application.

3.3. Competency enhancement: Return to the essence of education and prevent technological alienation

Centered on cultivating digital literacy among teachers and students, we balance instrumental value with educational value and uphold the original aspiration of fostering virtue through education. First, establish a hierarchical AI literacy curriculum system. Offer students courses in general artificial intelligence, digital ethics, and information literacy to strengthen higher-order thinking, innovation ability, critical thinking, and awareness of data security. Provide differentiated guidance based on educational stages: primary education focuses on AI cognitive enlightenment and standardized use; junior secondary education emphasizes logical thinking and information discrimination; senior secondary education centers on inquiry, innovation, and academic integrity. Second, strengthen the construction of teachers’ intelligent teaching capabilities. Carry out specialized training in human-machine collaborative instructional design, AI tool application, learning situation data analysis, and risk prevention and control. Reshape the role positioning of “teacher-led, AI-assisted” to alleviate technological anxiety and improve teaching innovation and risk response capabilities. Third, enhance humanistic literacy and emotional education. Guide teachers and students to rationally understand the instrumental nature of technology, emphasize emotional communication, ideological exchange, and value guidance between teachers and students, eliminate the tendency of “valuing technology over education,” and return to the true nature of education.

3.4. Scenario innovation: Deepen application across all educational stages and promote high-quality balanced development

Taking scenario implementation as the focus, and based on the cognitive laws of all educational stages, we will innovate human-machine collaboration models and promote the inclusive sharing of high-quality resources. First, implement differentiated applications by educational stage: basic education focuses on interest enlightenment, foundation consolidation, and habit formation; higher education emphasizes higher-order thinking, research competence, and innovation literacy; vocational education aligns with industrial needs and strengthens virtual training and job adaptability. Second, build an inclusive intelligent education resource system. Relying on the national smart education platform, we will use generative AI to develop standardized and high-quality resources such as lesson plans, courseware, virtual experiments, and personalized exercises, promote cross-regional and inter-school sharing, help improve the quality of rural education, and narrow the urban-rural educational gap. Third, deepen the innovation of human-machine collaborative teaching models, promote the in-depth integration of AI in intelligent lesson preparation, virtual teaching assistants, personalized learning, intelligent evaluation, interdisciplinary teaching, and other scenarios, realize the transformation from “teaching-centered” to “learning-centered,” implement tailored education on a large scale, and comprehensively improve the quality of education.

Policy regulation, technical optimization, literacy enhancement, and scenario innovation complement and coordinate with each other: policy serves as the guideline to define development boundaries; technology acts as a tool to consolidate the foundation of empowerment; literacy is the foundation to uphold the original aspiration of education; scenarios provide the basis to unlock application value. Only through the coordinated efforts of these four dimensions can we resolve multiple challenges, promote the safe, standardized, inclusive, and efficient application of generative AI in education, and inject new momentum into the construction of a strong country in education.

4. Conclusion and prospects

As a core technology in the digital transformation of education, generative artificial intelligence boasts advantages such as personalization, intelligence, interactivity, and generativity. It can optimize the entire process of teaching, learning, and evaluation, and possesses irreplaceable value in improving teaching efficiency, enhancing learning experience, promoting educational equity, and cultivating innovative talents. A systematic intelligent education application model has taken shape, with remarkable empirical results in teaching empowerment, learning quality improvement, and evaluation innovation. However, the current educational application of generative AI still faces core practical challenges, including technical hallucinations, ethical and security risks, weakened educational essence, and a widening digital divide, which severely restrict the full release of technology’s value in empowering education.

In response, this paper proposes a development path featuring “controllable technology, education-oriented, ethics-guaranteed, and collaborative governance.” By constructing an integrated application ecosystem of policy regulation, technical optimization, literacy improvement, and scenario innovation, it can effectively promote the standardized, healthy, and sustainable application of generative AI in education, and form an intelligent education application ecosystem that is safe and controllable, standardized and orderly, inclusive and balanced, as well as highly efficient in empowerment.

It can be predicted that multimodality, embodied intelligence, and education-specific large models

will become mainstream in the future, with further improvements in the accuracy of content generation and educational adaptability. Human-machine collaborative teaching will become normalized, and personalized learning, intelligent evaluation, and virtual training will become core scenarios. The integration of generative artificial intelligence and education is a long-term systematic project. It is necessary to uphold the original aspiration of education, take technology as the wing, ethics as the guideline, and education as the foundation, so as to promote the in-depth integration of technology and education and enable intelligent technology to truly serve the growth of every learner.

Disclosure statement

The authors declare no conflict of interest.

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