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INNOVATIVE PATHWAYS FOR GENERATIVE ARTIFICIAL INTELLIGENCE TO DRIVE DIGITAL TRANSFORMATION IN EDUCATION

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Abstract: In today's information society, which has entered the digital age, generative artificial intelligence is emerging as a pivotal factor driving the digital transformation in education. This transformation is now evolving into a new phase centered around generative AI, making it a core driver of educational digitalization. With the support of emerging technologies such as generative AI, the seamless transition toward digital education is being realized. The integration of generative AI in the digital transformation of education enables the establishment of new models for personalized talent development, facilitating a shift from the deficit-based education model rooted in the industrial society to a strength-based approach suited for the information society. It also contributes to the optimization of teaching processes, the improvement of instructional and learning behaviors among educators and students, and the enhancement of teaching effectiveness. Furthermore, it supports the co-creation and sharing of high-quality educational resources, promotes educational equity, and fosters the implementation of lifelong learning.
Keywords: Generative artificial intelligence; Digital transformation in education; Intelligent education

1 INTRODUCTION

Generative Artificial Intelligence (GenAI) refers to AI technology that utilizes deep learning, natural language processing, and other techniques to automatically generate new content or solve novel problems. On the other hand, the digital transformation in education signifies the process of shifting traditional educational models towards digital, networked, and intelligent paradigms. The connection between the two lies in the fact that GenAI provides the technical support necessary to drive the digital transformation in education, thereby accelerating its progress. Concurrently, this transformation offers abundant application scenarios for GenAI, fostering its innovation and development within the educational field. This synergy collectively advances the personalization, intellectualization, and popularization of education, providing robust momentum for innovation and development in the educational sector.

GenAI demonstrates immense potential and significance in the digital transformation of education. Through applications and innovations in personalized learning experiences, optimization of educational resource allocation, enhanced accuracy in educational assessment, and the promotion of educational intelligence and adaptability, GenAI not only offers students a superior learning experience but also provides teachers with more reliable instructional feedback. These advantages jointly drive the intellectualization and adaptability of education, supplying sustained impetus and support for the digital transformation in education and heralding even broader development prospects for the field [1].

This study aims to conduct an in-depth exploration of how GenAI drives the digital transformation in education and to elucidate its innovative pathways. By analyzing practical cases that integrate core GenAI technologies with educational principles, it seeks to clarify the application potential of GenAI in education and its role in propelling the digital transformation of the educational sector.

2 LITERATURE REVIEW

2.1 Generative Artificial Intelligence

In September 2023, UNESCO released the Guidance for Generative AI in Education and Research, defining generative artificial intelligence as a technology that automatically generates content based on prompts expressed by humans through symbolic representation systems of thought [2]. Miao Fengchun introduced the fundamental capabilities of generative AI from the perspective of pattern recognition and content generation in relation to human symbolic systems. He described generative AI as a simulation technology based on human symbolic representation systems, which utilizes generative pre-trained transformers to automatically produce new content in response to user-provided prompts or reference examples. This technology is capable of processing various forms of symbolic representation—such as natural language, graphics, images, music, and software code—demonstrating robust capabilities in both pattern recognition and content generation. Despite breakthroughs in certain areas, generative AI still lacks the ability to comprehend the real-world context behind texts, and its outputs may contain inaccuracies and biases. Therefore, it should be used with caution in high-stakes domains such as education. Recent technological advances indicate that generative AI has transcended the scope of large language models alone. Researchers have proposed the term "foundation models" to

more comprehensively capture its full implications. These developments offer groundbreaking opportunities for both upstream and downstream AI technology development [3].

The application of generative AI in education has facilitated comprehensive improvements in student creativity, agency, autonomy, and instructional efficiency. Wu Nanjing et al. from Southwest University argued that, from the perspective of the relationship between technology and humans, while generative AI offers new possibilities, it also introduces new forms of inequality. Although AI has transformed how humans understand the world and represents an inevitable historical trajectory for modern society, its essence remains that of a tool. It can be leveraged to promote intelligent and personalized education while enhancing overall efficiency [4]. Feng Yuhuan from Sun Yat-sen University suggested that the open nature of generative AI, exemplified by ChatGPT, fosters the development of innovative thinking among students. Its interconnected environment broadens students' knowledge horizons and deepens their intuitive understanding of subjects. The shift from one-way to interactive human–computer engagement enhances students' cognitive agency, while instant feedback strengthens deep learning capabilities. Personalized customization reinforces students' autonomy in choice and improves learning efficiency [5].

However, alongside the recognized advantages of generative AI in education, serious concerns have been raised regarding data security and ethical issues. Zhang Li et al. from Northeast Normal University contended that generative AI technology may lead to the homogenization of individual thought and the erosion of human agency, thereby constraining independent thinking and innovation. Moreover, over-reliance on generative AI could reduce interpersonal interaction among educational participants, hindering collaboration and communication, and ultimately causing the decline of intersubjectivity. Finally, the deterministic narrative of technocracy may push educational systems toward digital surveillance and a crisis of trust, undermining both the autonomy and effectiveness of educational governance [6]. Hence, the use of generative AI in education must be approached with vigilance regarding its potential impacts on human agency, individuality, and the educational ecosystem, so as to ensure harmonious coexistence between technology and humanity and promote the holistic development of education.

2.2 Digital Transformation in Education

In recent years, the rapid advancement of information technology has spurred a growing body of research in China on the digital transformation in education. Numerous scholars have conducted in-depth explorations into its background, significance, pathways, and strategies. Regarding the driving forces behind this transformation, some researchers point to the development of digital technologies, policy promotion, and market demands as key factors. Key research areas in this process include the development of digital educational resources, the creation of digital learning environments, and the innovation of technology-enhanced teaching models [7-8].

Furthermore, domestic scholars have carried out extensive case studies on the implementation of digital transformation in education. For instance, some have closely examined the development of online education platforms, the application of digital textbooks, and the construction of smart campuses, summarizing both successful experiences and persistent challenges. At the same time, issues such as the digital divide, information security, and privacy protection in digital education have also attracted widespread scholarly attention [9-10].

Similarly, research on the digital transformation in education is also abundant internationally, particularly in developed regions such as Europe and the United States, where digital education has an earlier start and thus a richer accumulation of theoretical and practical experience. For example, some studies have investigated the implementation of digital education across different countries and cultural contexts, comparing their strengths, weaknesses, and variations. Additionally, extensive research has been conducted on technology integration, learning outcome evaluation, and teacher professional development in digital education [11].

It is worth noting that Western countries have taken a leading role in educational innovation enabled by digital transformation. Several scholars, for instance, have documented advanced practices in countries such as the United States and the United Kingdom regarding policy formulation, technological R&D, and standard setting in digital education, offering valuable insights for the Chinese context [12].

In summary, the digital transformation in education has become a prominent research focus both domestically and internationally, yielding substantial outcomes in both theoretical and practical dimensions. Nevertheless, further deepening the development of digital education remains a task that requires continuous exploration and innovation.

3 MECHANISMS THROUGH WHICH GENERATIVE ARTIFICIAL INTELLIGENCE FACILITATES THE DIGITAL TRANSFORMATION OF EDUCATION

Generative artificial intelligence has achieved significant breakthroughs and transformations across multiple dimensions —including technological logic, outputs, and implications—injecting new momentum into the digital transformation of education and bringing unprecedented opportunities. Through deep integration with the future of education, generative AI is poised to reshape the forms and structures of human education and learning. This reshaping will manifest in various aspects, such as relationships among educational actors, learning environments, educational resources, instructional methods, assessment systems, and ethical governance. Such changes will not only enrich and expand the connotation and extension of education but also promote equity, enhance quality, and lay a solid foundation for building a lifelong learning system for all.

3.1 Advancing from Human–Machine Collaboration to Human–Machine Symbiosis: Reshaping Relationships Among Educational Actors

Generative AI is leading humanity and machines into a new era of symbiotic coexistence, marking an advanced stage in human–machine collaboration. In this symbiotic relationship, humans and machines are no longer in a simple assistive relationship but complement each other's strengths and potentials. Machines are no longer merely tools for augmenting human intelligence; rather, they deeply integrate with human intelligence, enabling more profound and higher-level interaction, collaboration, and fusion. This symbiotic relationship will drive progress and development in human society and create a better future [13].

Generative AI not only transforms the nature of the relationship between humans and machines but also promotes mutual growth and inspiration through iterative cross-development. This deep integration introduces new growth points in educational content and offers infinite possibilities for co-creation between humans and machines. At the same time, as humans and machines continue to develop and engage in high-level interaction, we continuously generate new data corpora, providing a continuous source of inspiration and momentum for AI algorithms. By analyzing the educational computing and neurocognitive mechanisms underlying human–machine interactions, we can further stimulate the emergence of collective intelligence and promote sustained progress and innovation in education [14].

Generative AI is also driving a shift in educational actor relationships from the traditional "teacher–student" model to a new "teacher–student–machine" tripartite structure. As machine intelligence continues to advance, the originally binary "teacher–student" relationship is gradually being replaced by a tripartite framework. In this new structure, generative AI empowers both teachers and students. For example, it can act as a virtual expert, intelligent teaching assistant, or data analysis aide, supporting teachers' professional development. Similarly, it can serve as an intelligent tutor, speaking partner, or debate opponent for students, facilitating personalized growth. In this way, every teacher gains an AI-assisted collaborator, and every student receives a personalized learning companion.

In response to this transformation, teachers and students must actively embrace the "machine" as a new actor in education. First, they need to learn about AI—understanding the basic principles and application scenarios of generative AI to enhance their technical proficiency. Second, they must master appropriate methods for using generative AI to ensure that the technology provides scientific and effective support for education. Finally, they should engage in co-learning with AI, leveraging it to improve teaching outcomes while guiding the adaptive development of the technology, thereby achieving deep, bidirectional integration of technology and education.

3.2 Promoting the Adoption of Generative AI in Education and Strengthening the Digital Learning Environment

Domain-specific large educational models represent a necessary direction for generative AI in the digital transformation of education [1]. Although general large language models hold significant potential for educational reform, their application in educational contexts requires higher standards of knowledge accuracy, ideological security, and adaptability to diverse subjects and grade levels. Directly applying general models not trained on specialized educational data may introduce algorithmic and data biases, potentially affecting the academic judgment and decision-making of teachers and students [15]. Such issues could lead to fragmented knowledge structures or even generate discriminatory content. Therefore, constructing and applying high-quality, domain-specific large models tailored to education is crucial. Such models can mitigate bias in content creation, improve the accuracy of educational knowledge, and ensure ideological controllability and security. This will provide a solid foundation for the digital transformation of education while driving the intelligent upgrading of information-based teaching environments.

Building educational large models on the foundation of general models can empower the intelligent upgrading of teaching platforms, tool applications, and educational products. For example, leveraging the multi-turn dialogue and scenario-generation capabilities of educational large models can optimize language learning tools, enabling intelligent oral proficiency assessment and precise grammar correction, and creating free conversational contexts with digital avatars—thereby significantly enhancing the effectiveness and usability of language learning tools. Furthermore, the multimodal capabilities of specialized models can upgrade teaching tools. Through voice interaction and data analysis assistants, they can intelligently generate classroom teaching quality reports and student learning progress reports, enhancing the intelligence of teaching tools and products and providing robust technical support for improving teaching efficiency and quality.

3.3 Enhancing the Supply and Innovation of Generative Teaching Resources

The production mode of teaching resources is undergoing a profound transformation—shifting from traditional manual creation to intelligent generation. In the rapid development of digital education, the role of digital resources has become increasingly prominent. At present, the development of digital teaching resources in China is characterized by multi-stakeholder collaboration, multi-user participation, and diverse sharing models. However, we must also confront practical challenges such as the scarcity of high-quality resources, limited variety, low development efficiency, and uneven quality.

The emergence of generative AI offers new opportunities to overcome these bottlenecks. Its powerful capabilities for rapid, synchronous, and multi-terminal intelligent generation make it possible for human–machine collaboration in resource development, enabling batch, massive, and efficient resource production. This will free more human resources

from tedious resource production tasks, allowing them to focus on more scientific content control and creative generation.

In the intelligent era, the way teaching resources are accessed is also undergoing profound changes. The traditional model of "people searching for resources" is shifting toward "resources finding people." Currently, although digital teaching resources on the internet are abundant and diverse, their quality is inconsistent, the logical relationships among resources are chaotic, and the supply mechanisms are imperfect. This undoubtedly poses significant challenges to the retrieval, screening, and utilization of teaching resources, while also increasing the cognitive burden on teachers and students.

In the practice of educational digitalization, how to shift the focus from merely generating teaching resources to better meeting the needs of teachers and students and providing customized resource services has become a user concern. Unlike traditional search engines, generative AI can intelligently aggregate and reorganize digital teaching resources, generate clearly structured and semantically logical textual results, and deliver precise recommendations. This shift transforms the acquisition of teaching resources from passive distribution to active recommendation, enabling demand-driven and personalized resource services, and providing teachers and students with a more convenient and efficient learning experience.

3.4 Intelligent Transformation of Teaching and Learning Methods

Unlocking the infinite potential of teaching innovation to comprehensively reduce teacher workload, improve quality, and increase efficiency. In actual teaching practice, teachers face heavy pressures from lesson preparation, instruction, and related tasks, while also dealing with the technical challenges brought by new technologies and equipment during the digital transformation. These dual pressures urgently require effective solutions.

Generative AI, with its exceptional content generation capabilities, precisely meets the daily teaching needs of educators. It provides strong support in various stages such as instructional design, classroom teaching, after-class tutoring, and assignment design and grading. For example, it can generate lesson plans and courseware with one click, significantly reducing the preparation burden on teachers. At the same time, it can expand classroom knowledge content and stimulate students' curiosity. It can even automatically extract key points from student essays, facilitating efficient grading. These functions not only alleviate the workload of teachers but also allow them to devote more energy to teaching innovation.

Moreover, generative AI reduces the difficulty of human–machine interaction, helping teachers overcome technical barriers. Through online platforms, teachers can easily engage in conversational interactions with AI without worrying about complex technical operations.

At the same time, we actively promote innovation in dialogic learning methods to meet the needs of personalized student learning and higher-order thinking cultivation. The Action Plan for Deepening Curriculum and Teaching Reform in Basic Education explicitly proposes the advancement of "digital empowerment for teaching quality improvement" to establish new learning models in the digital context. In this model, learning is gradually shifting from standardization to personalization, from passive reception to active inquiry, and from supply-side driven to adaptive provision.

The dialogic interaction features of generative AI enable it to deeply explore students' learning contexts and task requirements, generating diverse learning materials such as texts, images, videos, and audio, thereby providing students with rich learning resources. It can also recommend suitable learning paths and tasks based on students' learning levels, styles, and knowledge backgrounds, generating customized learning scaffolds. This not only helps improve students' collaborative, creative, and critical thinking skills but also motivates them and unlocks their potential, enabling higher-level personalized learning.

3.5 Emphasizing AI Ethics and Morality

In the process of promoting the digital transformation of education through generative AI, it is particularly important to balance the innovation of intelligent educational applications with attention to AI ethics and morality. This transformation not only represents a comprehensive renewal of educational forms, content, and methods but also reflects the deep integration of and forward-thinking about technological development in the field of education.

Through the introduction of generative AI, we can achieve a series of innovative applications, such as the design of personalized learning paths, the construction of intelligent teaching assistance systems, and the automatic generation and updating of learning resources. These innovations not only help improve teaching effectiveness but also stimulate students' interest and potential, providing them with richer and more diverse learning experiences. However, while pursuing technological innovation, we must not overlook the importance of AI ethics and morality. Education is a sacred undertaking related to the future of humanity and the shaping of values; the introduction of any technology must undergo strict ethical and moral review. We need to ensure that the application of generative AI in education does not infringe on student privacy, exacerbate the digital divide, or mislead students' value judgments, among other concerns.

To this end, we must establish a sound ethical and moral framework that clearly defines the boundaries and limitations of AI use in education. In addition, we need to strengthen the supervision and evaluation of AI technology. Through regular technical audits, risk assessments, and user feedback collection, we can ensure that the application of generative AI in education remains controllable, safe, and effective. At the same time, we should actively advocate the concept of

"technology for good," guiding technical personnel and educators to jointly shoulder the responsibility and mission of cultivating qualified talents for society.

4 CONCLUSION

Generative Artificial Intelligence plays a pivotal role in the digital transformation of education, driving educational reform through innovative pathways. First, it enables personalized learning by tailoring educational resources and pathways to individual students' learning characteristics and needs, thereby enhancing learning outcomes. Second, generative AI can automatically produce diverse and abundant learning content, alleviating the workload of educators while providing students with access to a broader spectrum of knowledge. Furthermore, it facilitates the construction of intelligent teaching assistance systems that employ data analytics and smart algorithms to support teachers in making informed instructional decisions and refining pedagogical strategies.

In terms of innovative pathways, generative AI breaks away from traditional educational models through its deep integration with the educational domain, creating more diversified, interactive, and adaptive learning experiences. Leveraging big data and machine learning technologies, it continuously optimizes educational resources and services to meet students' evolving learning demands. At the same time, generative AI promotes a shift in educational dynamics—from a teacher-centered approach to a student-centered paradigm—fostering greater student initiative and creativity. However, amid advancing the digital transformation of education, it is essential to address ethical considerations related to AI and establish corresponding regulatory and oversight mechanisms. This will ensure that the application of generative AI aligns with ethical and legal standards, ultimately benefiting students and society at large.

As the digital transformation of education progresses, generative AI will become deeply integrated across all aspects of the educational landscape, fostering more pluralistic, interactive, and adaptive learning experiences. It will accelerate the transition from a traditional teacher-centered model to a learner-oriented approach, stimulating students' autonomy and innovative capacities. Simultaneously, generative AI will contribute to a more balanced distribution of educational resources, narrowing regional and urban–rural educational disparities and expanding equitable educational opportunities for all.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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