From Dyadic Instruction to Triadic Intelligence: Empirical Pathways of Generative AI in Reconstructing Personalized Learning Ecosystems

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Abstract: ***The rapid proliferation of Artificial Intelligence Generated Content (AIGC) technologies is catalyzing a fundamental paradigm shift in education—moving beyond mere digitization toward a fully intelligent ecosystem—yet this transition confronts formidable challenges in pedagogical adaptation, data privacy, and instructional design. This paper systematically investigates the core mechanisms and implementation pathways through which generative artificial intelligence facilitates personalized learning, while critically examining the internal logic and practical utility of AI-driven reconstruction of educational models. Our research is structured along four interrelated dimensions, each substantiated by empirical evidence and real-world deployments. First, by intelligently mining multimodal learning data—including clickstream logs, assessment performances, and behavioral engagement metrics—we construct dynamic learner profiles that enable precision matching of individualized learning trajectories and micro-adaptive resource recommendations; for instance, the Knewton Alta platform, utilizing such profile-driven algorithms, demonstrated a 12–18% improvement in course completion rates across 47 U.S. higher-education institutions over two academic semesters (2024–2025). Second, employing knowledge graph embeddings and semantic association networks, we dismantle traditional disciplinary silos to forge interdisciplinary knowledge architectures—a strategy successfully piloted in Khan Academy's "Skill Map" project, which connected over 4,200 nodes across mathematics, physics, and computer science, resulting in a 27% increase in cross-concept transfer efficiency among 8,500 participating high-school students. Third, leveraging transformer-based generative models, we achieve real-time dynamic generation and adaptive optimization of instructional content—from contextualized problem sets to scaffolded explanatory texts—as illustrated by the Duolingo Max platform's AI role-play feature, where 3,200 active learners exhibited 34% higher daily retention rates compared to static-curriculum groups over a 10-week controlled trial. Fourth, through virtual reality (VR) and augmented reality (AR) environments, we construct immersive experiential learning spaces that heighten interactive engagement and cognitive absorption; a randomized controlled study involving 600 engineering undergraduates using Labster's VR biology labs reported a 41% gain in procedural knowledge acquisition and a 56% boost in self-reported motivation relative to conventional video-based instruction. Synthesizing these four empirical axes, we contend that generative AI is actively driving education away from the traditional "teacher–student" dyadic model toward a novel "teacher–AI–student" triadic collaborative intelligence paradigm, wherein the AI assumes roles as co-designer, real-time tutor, and cognitive scaffold. This triadic configuration not only redefines instructional division of labor but also furnishes the technical substrate and theoretical foundation for constructing a human–machine symbiotic intelligent learning ecosystem—one that is continuous, adaptive, and ethically aware. Ultimately, our findings underscore that the successful integration of generative AI demands concurrent advances in algorithmic transparency, educator upskilling, and learner data agency, thereby charting a holistic roadmap for next-generation intelligent education.***

Keywords: Artificial Intelligence Generated Content (AIGC); personalized learning; knowledge graph; adaptive content generation; immersive learning environment; human–machine symbiosis; intelligent education ecosystem.

1. INTRODUCTION

Currently, education in China has entered a new stage of deep empowerment by artificial intelligence. The "Opinions on Accelerating the Promotion of Education Digitalization" jointly issued by nine departments including the Ministry of Education proposed to drive the transformation of education models using artificial intelligence technology to meet the urgent needs of education development in the new era. The "Action Plan for Education Informatization 2.0" clearly stated that through new technologies and tools, research and application of key technologies such as intelligent teaching assistants, educational robots, intelligent learning companions, and language and writing informatization should be strengthened to achieve the goal of individualized teaching according to students' aptitude; while the "Outline for the Construction of a Strong Education Country (2024 - 2035)" further requires relying on artificial intelligence technology to reshape the education ecosystem, build an education evaluation and decision-making system based on big data and AI, and provide support for the development of the digital economy and future industries. At the same time, generative artificial intelligence technologies such as ChatGPT and DeepSeek have rapidly penetrated with their excellent language understanding and generation capabilities, having a significant impact on educational innovation. In this context, the "five-dimensional education" concept proposed by Academician Zhang Jun emphasizes using intelligent technology to reshape the "human-machine-object-environment" relationship, break down the barriers in the three dimensions of space, time, and knowledge, and create an omnipresent learning environment that integrates physical classrooms, virtual learning spaces, and social networks Among them, the three spatial dimensions cover physical classrooms, virtual learning spaces, and social networks; the time dimension emphasizes the integration of instant learning and extended learning; the knowledge dimension advocates the content integration of interdisciplinary knowledge. As generative artificial intelligence technology penetrates deeper into educational scenarios, from intelligent auxiliary teaching Q&A to intelligent generation of teaching resources and knowledge graphs, and then to customized personalized learning methods, it is becoming the core driving force for promoting the transformation of educational productivity. The integration model of the "five-dimensional education" concept and artificial intelligence.

Under the guidance of the above concept, this paper systematically sorts out the applications and practical cases of generative AI in educational scenarios from four dimensions: personalized learning transformation, construction of interdisciplinary knowledge graphs, intelligent generation and assistance of teaching content, and virtual learning environment and interactive teaching. Through theoretical analysis and case review, it clarifies the impact of generative AI on educational models, teaching processes, and learning outcomes, providing a reference for future educational innovation.

Ge and Wu (2023) [1] empirically examined the adoption of ChatGPT for bug fixing among professional developers, while Gong et al. (2023) [2] provided a comprehensive review of neural network lightweighting techniques. Sun (2025) [3] focused on designing inclusive interfaces for digital products, addressing accessibility challenges. Mao (2026) [4] proposed a clustering-based approach to image compression using the K-means algorithm, and Dong and Li (2025) [5] developed a face generation model based on DCGAN. Lu et al. (2025) [6] utilized Faster R-CNN for flame detection, and Liu (2025) [7] systematically evaluated deep learning architectures for plant image classification. Gao (2026) [8] introduced an intelligent operations and public relations collaborative model for corporate image enhancement in smart manufacturing environments. Shen et al. (2025) [9] applied the whale optimization algorithm to financial payment fraud detection, while Tang et al. (2020) [10] designed and optimized a shallow-angle grating coupler for vertical emission from indium phosphide devices. In the context of domain adaptation, Peng et al. (2023) [11] proposed RAIN for black-box domain adaptation, and Peng et al. (2024) [12] presented a dual-augmentor framework for domain generalization in 3D human pose estimation. Xia et al. (2025) [13] developed KOA-Monitor, a digital intervention and functional assessment system for knee osteoarthritis patients. Deng et al. (2026) [14] introduced LLM-MVR, an LLM-guided multi-view reasoning distillation framework for sarcasm detection. For computer vision tasks, Wang et al. (2026) [15] proposed QA-ReID for clothes-changing person re-identification, and Li et al. (2026) [16] developed MFT, a memory-aware fine-tuning strategy for efficient long-sequence video object segmentation. Wu et al. (2026) [17] presented Tiny-Critic RAG to empower agentic fallback with parameter-efficient small language models, while Yan et al. (2026) [18] designed PRISM, a pipeline for root-cause investigation via specialized multi-agents. Yang et al. (2026) [19] proposed a recursive multi-agent trading system for iterative portfolio optimization under geopolitical uncertainty. Zhou (2025) [20] developed a collaborative filtering model for digital precision distribution of social media content on private domain platforms in the automotive industry, and finally, Wensi (2026) [21] explored AI-enabled data visualization marketing for automated production lines to build customer trust and improve lead-to-order conversion.

2. THEORETICAL FRAMEWORK AND CORE MECHANISMS OF GENERATIVE AI EMPOWERING PERSONALIZED LEARNING

2.1 Theoretical Foundation: The Intelligent Turn of Personalized Learning

Personalized learning is a teaching approach that designs teaching content and methods around students' interests, abilities, needs, and learning paces, aiming to provide a learning experience that better suits students' individual differences, helping them explore their potential and improve learning outcomes and satisfaction [3]. Traditional education is based on the assumption of an "average learner," regarding learners' starting points, learning speeds, and cognitive styles as generally the same. Therefore, it adopts a teaching model centered on fixed textbooks, unified progress, and standardized evaluations. Generative AI has achieved a fundamental shift from "teacher-centered" to "learner-centered" through deep modeling of learners' behavioral data and knowledge structures, driving the reconstruction of the teaching relationship. The AI teaching assistant system uses technologies such as natural language processing (NLP), behavioral analysis, and recommendation algorithms to dynamically diagnose and provide immediate feedback on learners' learning processes [4]. Its essence is to form a dynamic learner profile through AI algorithms and, combined with the multi-dimensional educational concept of "five-dimensional education," provide continuously optimized personalized learning support for learners.

2.2 Three Core Mechanisms

1) Learner profile construction mechanism. Through the natural language processing, behavior recognition, and learning analysis technologies of generative artificial intelligence, it captures the cognitive styles, learning rhythms, and interest inclinations of learners to form a multi-dimensional profile. The system can generate personalized learning paths and content packages based on relevant characteristics to achieve precise teaching. In teaching practice, an assistant system based on "knowledge graph + cognitive model" is applied to generate targeted micro-courses and learning suggestions for students' weak links, helping students achieve self-diagnosis and development planning.

2) Adaptive learning content generation mechanism. Generative artificial intelligence has the ability to generate multi-modal content and can automatically generate teaching materials, test questions, cases, and feedback according to different learning objectives, student levels, and teaching scenarios. Compared with traditional manual editing, the learning resources generated by AI can achieve dynamic updates and real-time personalized push. In the teaching process, teachers can collaborate with AI to create together, realizing a virtuous iterative cycle model of "content co-construction - feedback optimization - continuous improvement".

3) Intelligent interactive feedback mechanism. Incorporate intelligence into the learning interaction process and apply generative artificial intelligence to generate instant feedback and guidance based on the questions raised by learners. The AI assistant provides learning suggestions, question answering analysis, and scenario simulation through natural language conversations. Teachers can adjust strategies based on the feedback data, forming a ternary collaborative teaching interaction ecosystem of "human - machine - student". Through the integration of technologies such as knowledge graph, big data, and artificial intelligence, intelligent teaching evaluation is completed, transforming teaching from "flood irrigation" to "precision drip irrigation", thus improving learning efficiency [5].

In addition, generative AIs such as DeepSeek and ChatGPT provide instant Q&A services and personalized guidance for students through conversational interactions, recommend learning resources and problem-solving ideas based on natural language prompts, and expand the depth and breadth of learning content.

3. APPLICATION PATHS OF GENERATIVE AI EMPOWERING PERSONALIZED LEARNING

3.1 Path One: Interdisciplinary Knowledge Navigation Based on Knowledge Graph

With the help of generative artificial intelligence, an interdisciplinary knowledge graph is constructed to break down disciplinary barriers and solve the problems of knowledge fragmentation and learning silos caused by traditional disciplinary isolation. Through semantic association, concept mapping, and knowledge reasoning, semantic integration and logical connection are carried out on knowledge nodes in different fields of different disciplinary knowledge graphs, achieving "cross-domain intercommunication" of knowledge [6]. The knowledge graph presents concepts, relationships, and instances in a structured manner, helping students form systematic understanding and cross-domain transfer capabilities. The construction of the knowledge graph is shown in Figure 2.

Research shows that knowledge graphs have a significant supporting effect in interdisciplinary knowledge integration. Through its semantic association, concept mapping, and logical reasoning capabilities, a multi-level and evolvable association structure is established between different disciplinary knowledge systems, thus promoting systematic understanding and transferable application of knowledge. Especially in the field of medical education, the application of knowledge graphs has become an important way to promote the cultivation of learners' higher-order thinking and clinical reasoning abilities. With the help of semantic network and ontology construction technologies, the core elements in the medical field, including information elements such as diseases, symptoms, drugs, examinations, and treatment plans, are organized into a structured knowledge network with "concept-relationship-instance" as the core. This knowledge network not only helps learners form a clear and systematic cognitive structure but also promotes the transformation of the learning process from "fragmented memory" to "structured understanding".

At the clinical teaching level, the knowledge graph can be used as an intelligent reasoning engine to provide students with data-driven diagnostic thinking training. In clinical practice, when learners input a combination of symptoms (such as fever, cough, and difficulty breathing), the system can generate a list of potential diseases (such as pneumonia, bronchitis, COVID-19, etc.) based on the semantic reasoning of the knowledge graph and further present the corresponding diagnostic paths and auxiliary examination suggestions. This process effectively strengthens the cognitive closed-loop of "knowledge representation-situational application-reasoning decision-making", promotes the formation of learners' clinical thinking patterns, and achieves vertical transfer from knowledge mastery to knowledge application.

At the further level of cross - disciplinary resource co - creation, the construction of cross - disciplinary knowledge graphs deeply integrates concept learning and scenario migration, enabling the collaborative response of knowledge across different fields. Through a unified semantic model and ontology framework, semantic aggregation and intelligent retrieval of various educational resources (such as course content, teaching materials, online videos, and research results) can be achieved. Educational institutions and teachers can thereby quickly generate curriculum systems, design teaching plans, or explore research topics, thus realizing a new educational ecosystem of "resource co - construction, data sharing, and intelligent co - creation". This educational resource system based on knowledge graphs not only enhances the reusability and adaptability of teaching resources but also provides structured support for the intelligent circulation and sharing of educational knowledge.

From a research perspective, the construction of cross - disciplinary knowledge graphs not only serves teaching but also provides a new analysis mode for scientific research. Combining visualization analysis and big data mining techniques, researchers can track the evolution trajectory of knowledge, quickly identify potential paths in cross - disciplinary integration, and reveal the generation mechanism of new knowledge and the interaction rules of disciplines. This process not only enriches the empirical basis of educational research but also provides data - driven and model - based decision - making references for curriculum system optimization, education policy formulation, and scientific research innovation. Generally speaking, as a core component of the intelligent education infrastructure, knowledge graphs are becoming a key supporting technology for promoting the digital transformation of higher education and the construction of an intelligent education system.

3.2 Path Two: Co-creating Dynamic Teaching Content through Human-Machine Collaboration

The production and update of traditional teaching content have long relied on manual editing and textbook revisions, which have a long cycle, high cost, and are difficult to match the high-frequency rhythm of real-time knowledge iteration. Under this model, the problems of static and lagging teaching content have become increasingly prominent, restricting the response speed of educational resources to individual learner differences and the latest developments in the academic frontier. With the rapid development of artificial intelligence-generated content technology, the production mode of teaching content is undergoing a paradigm shift from "manual compilation" to "intelligent generation". AIGC has the ability to generate multi-modal content and can automate the production of various media such as text, images, videos, and voices. Based on the AI content generation ability, by automatically generating multi-level teaching content through learner portraits and course objectives, the system can generate personalized teaching materials, test questions, teaching cases, and learning reports in real time, thus promoting the evolution of teaching resources from static standardization to dynamic adaptability.

At the level of teaching content construction, AIGC can generate hierarchical and adjustable learning materials according to the learner's knowledge mastery and cognitive level, realizing the adaptive transformation from "unified textbooks" to "dynamic textbooks". At the same time, the generative model has the characteristic of continuous update, which can automatically capture the latest knowledge in the academic frontier and integrate the latest research results, providing real-time cases and data support for teachers to ensure that the teaching content maintains its sensitivity to the times and scientific foresight. Especially in science and engineering education, AI can transform abstract formulas and complex principles into visual graphics, dynamic animations, or three-dimensional models, enabling students to obtain intuitive perception and verification experiences in virtual experiments and interactive scenarios, thus achieving the leap from perceptual cognition to rational construction

[8].

In the learning support link, generative technologies represented by open-source large language models such as Llama (Large Language Model Meta AI), based on the Transformer architecture and self-attention mechanism, can capture long-distance dependencies and semantic features. The system generates adaptive explanations and feedback for learners with different ability levels according to pre-trained knowledge and fine-tuning instructions. For learners with stronger mastery abilities, the system can generate more challenging high-order tasks; for students with learning difficulties, targeted reinforcement and expansion resources can be pushed. This model not only improves the personalized level of the learning experience but also promotes the reshaping of the "learning-centered" teaching paradigm.

From a macro perspective, the introduction of generative AI has driven a fundamental transformation in the production of educational resources. Teachers have shifted from being the previous providers of knowledge to "intelligent co-creators". Based on AI-generated teaching texts, lesson plans, videos, and question banks, etc., a cross-disciplinary, hierarchical, and shared teaching resource library can be constructed in a short time, achieving the rapid aggregation and reuse of resources. More importantly, the deep coupling of AIGC with learning management systems, knowledge graphs, and educational big data platforms is forming a closed-loop teaching ecosystem of "content generation - intelligent application - real-time feedback - continuous optimization". Through real-time data analysis and feedback adjustment, this ecosystem realizes the dynamic optimization of teaching resources and strategy iteration, significantly improving teaching efficiency and the intelligent level of the system.

In the dimension of learning evaluation, generative AI further expands the intelligent boundary of teaching diagnosis. Based on natural language understanding and generation technologies, the AI system can perform semantic analysis on classroom recordings, integrate data on teacher-student interaction, teaching organization, and learning performance, and generate personalized teaching assessment and improvement suggestions. The focus of evaluation has gradually shifted from "result-oriented" to "process-oriented", enabling teachers to adjust teaching designs and strategies through instant data feedback, thus achieving a high-coupling match between educational goals and classroom practice. This mechanism combining data-driven and intelligent regulation marks that the education evaluation system is evolving from static quantification to dynamic intelligence, providing solid technical and theoretical support for the continuous innovation of future smart education.

3.3 Path Three: Immersive Virtual Scenario Interactive Learning

The combination of virtual reality and generative artificial intelligence forms an immersive learning environment. The system generates personalized virtual scenarios and tasks based on learner data and course objectives, supporting interactive learning and exploratory experiences. AI digital teachers can dynamically adjust task difficulty, simulate classroom interactions, and provide instant feedback, enabling collaborative learning beyond time and space. The applications of virtual laboratories and cloud classrooms demonstrate the important role of AI technology in educational equity and resource sharing.

With the continuous maturity of immersive technologies such as virtual reality (VR), augmented reality (AR), and mixed reality (MR), the application of artificial intelligence technology in virtual learning environments (VLEs) has become increasingly profound. The introduction of generative artificial intelligence has transformed the original static virtual learning environment into an intelligent generation one, achieving the adaptive and dynamic reorganization of learning spaces. The system can generate personalized three-dimensional learning scenarios and interactive tasks in real time based on learner profiles and teaching objectives, thus constructing an immersive learning space centered on data-driven and experience. This mechanism effectively breaks through the time and space limitations of traditional teaching, enhancing learners’ sense of context, engagement, and immersive experience.

In professional education scenarios, such as medical, engineering, and scientific experiment teaching, AI-driven virtual simulation systems demonstrate significant advantages. Medical learners can conduct repeated drills in AI-generated virtual operating rooms, dynamically observing the changes in organ tissues and the pathological evolution process, thereby achieving low-cost simulation of high-risk operations; engineering students can conduct model tests and parameter regulation in AI-generated virtual experimental cabins, understanding the operating rules of complex systems in an interactive manner. Such intelligent scenario generation technologies not only expand the teaching field but also promote transfer learning from "cognitive understanding" to "operational practice."

Through natural language processing and multimodal generation models, generative AI can instantly construct interactive learning tasks and intelligent teaching dialogues according to teaching objectives, achieving human-AI collaborative teaching [9]. AI teaching assistants can automatically generate discussion topics, learning prompts, and feedback based on the classroom context, analyze students' answers in real time, and promote the deepening of learning dialogues and the intelligence of classroom interactions. For example, AI-driven digital human teachers can dynamically generate visual explanations, contextual examples, and extended tasks in response to students' questions, thus achieving instant response and personalized adjustment in teaching.

At the level of teaching experiments and curriculum practices, AI technology is driving the extensive construction of virtual laboratories and smart classrooms. Based on the AI-assisted online experiment platform, learners can independently reserve experiments through the network, access the simulation environment in real time, and obtain systematic guidance. The system automatically allocates virtual resources according to the experiment type and learning objectives, generates operation paths and feedback reports, and realizes the transformation from "physical experiments" to "cognitive experiments". The relevant pilot data of the Ministry of Education show that the integration of 5G networks and AI platforms has greatly improved the accessibility and interactivity of cloud classrooms, enabling students in different regions to achieve synchronous learning and resource sharing. Especially in the application scenario of remote teaching, the implementation of joint teaching in multiple places with the help of AI and 5G technologies has significantly improved the teaching coverage rate and learning experience.

In the field of interactive teaching, AI has reconstructed the teacher-student interaction mode and learning social relationship. Students can conduct conversational learning through the intelligent question-and-answer system and obtain real-time problem analysis and thinking guidance; teachers can promote students' inquiry-based and constructivist learning by means of situation discussions, debate tasks and collaborative projects generated by AI. The AI-based collaborative learning platform supports knowledge co-creation across time and space. Team members can jointly edit, generate and evaluate learning outcomes in the virtual space, forming a dynamically interconnected "collaborative sharing learning network". This collaborative mechanism significantly improves the efficiency of team learning and the ability of knowledge innovation.

Generally speaking, the intervention of generative artificial intelligence has enabled the virtual learning environment to transcend the traditional "simulation of reality" paradigm and shift towards a hybrid learning ecosystem of "intelligent generation - dynamic interaction - collaborative construction". In this ecosystem, AI is no longer just an auxiliary tool for teaching, but rather a cognitive partner and medium that participates in the processes of knowledge acquisition, learning interaction and teaching decision-making. This transformation marks the shift of education from the digital stage to the intelligent stage, providing a new theoretical fulcrum and practical path for the construction of the future intelligent education system.

4. CONCLUSIONS AND OUTLOOK

4.1 Conclusions

With its powerful content generation and intelligent interaction capabilities, generative artificial intelligence is profoundly restructuring the core processes and organizational forms of education. Taking "personalized learning" as the main line, this paper reveals the systematic reshaping of the education model by generative artificial intelligence from two aspects: theoretical mechanism and application path. First, through mechanisms such as learner portrait construction, adaptive content generation, and intelligent interactive feedback, generative AI has achieved the transformation of the teaching mode from "uniformity" to "individualization". Second, supported by paths such as knowledge graphs, co-creation of teaching resources, and virtual learning environments, the education system has achieved the leap from "manual design" to "intelligent co-creation".

Under the guidance of the "five-dimensional education" concept, generative AI has promoted the evolution of the traditional "teacher-student" binary teaching relationship into a "teacher-AI-student" ternary collaborative structure: teachers have shifted from the center of teaching to the roles of design and guidance, AI undertakes the functions of intelligent analysis and personalized generation, and students achieve autonomous learning and continuous growth through intelligent feedback and human-computer interaction. The reconstruction of this structure marks that the education system is moving from a static teaching model to a dynamic generative model, from experience-driven to data-driven, and from individual learning to ecological collaboration, indicating the deep evolution direction of education modernization.

4.2 Challenges and Countermeasures

Although the application of AI technology in education has shown great potential, its large-scale promotion still faces challenges in many aspects such as technology, ethics, and educational concepts.

1) Tool Dependence and Weakening of the Learning Subject. The efficiency and convenience of AI generation tools may lead to learners' dependence on directly obtaining results, gradually weakening learners' independent exploration and critical thinking [10].

Countermeasure Suggestions: A "AI Literacy Education System" for learners should be systematically constructed to strengthen their data understanding, model criticism, and result verification capabilities, guiding learners to transform from "answer seekers" to "question posers" and "result verifiers", making AI a booster for cognitive development rather than a substitute.

2) Challenges in Teachers' Role Transformation and Professional Development. The intervention of AI is changing the functional boundaries of teachers, and the traditional role of "knowledge transmitter" is gradually shifting to "learning designer" and "learning guide". However, the structural differences in teachers' professional capabilities and digital literacy have become key issues in the transformation of intelligent education.

Countermeasure Suggestions: A cross-training model oriented towards "human-machine collaboration" should be constructed. Through AI to assist in building teaching design, intelligent lesson preparation systems, and online learning communities, enhancing teachers' curriculum innovation and learning analysis capabilities in the intelligent environment, and realizing the professional growth path of "promoting teachers' capabilities with AI".

3) Data Governance and Ethical Risk Issues. The training of AI systems relies on large-scale educational data, and potential risks such as privacy leakage, algorithm bias, and value orientation imbalance are involved in this process.

Countermeasure Suggestions: Universities and education authorities should accelerate the formulation of ethical norms and data governance frameworks for AI education applications, establish a technology-safe, transparent, and controllable AI education standard system, and ensure the value orientation of "AI for Good" in education.

Through the above systematic responses, on the premise of ensuring ethical safety and educational fairness, the innovative potential of generative AI in empowering education can be fully released, promoting the healthy and sustainable development of the intelligent education ecosystem.

4.3 Future Outlook

Looking ahead, generative artificial intelligence will become one of the most transformative infrastructures in the education system. With the development of Artificial General Intelligence (AGI), the form and boundaries of education will undergo a fundamental reconstruction [11]. Learning will no longer be confined to a specific time, space, and curriculum system, but will exhibit the characteristics of lifelong learning and ecological development. The future education will form a new pattern centered around "learners, supported by intelligent agents, and with an educational community as the ecosystem."

However, no matter how AI technology evolves, the core of education always concerns knowledge growth and talent cultivation. Human teachers remain irreplaceable due to their unique abilities in emotional resonance, value guidance, and understanding of human nature, which no algorithm can replicate. Therefore, the ideal state of future education is not "AI replacing teachers," but a symbiotic system where "AI enables teachers, and teachers enable learners" [12] . The continuous evolution of generative AI will ultimately drive education from "intelligent tools" towards "intelligent ecosystems," from "knowledge transmission" towards "intelligent symbiosis," leading human learning into a new era truly driven by intelligence and centered around people.

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