Artificial Intelligence and Digital Technology

Review

Research on the Intelligent Reform Pathway of Higher Education Empowered by Generative Artificial Intelligence

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Abstract: The rapid advancement of generative artificial intelligence (GAI) has reshaped university teaching models and learning practices, emerging as a central force in instructional innovation and driving the broader digital transformation of higher education. Centered on teaching reform, this paper conducts a systematic analysis of how GAI enhances instructional processes through multimodal resource generation, dynamic learning-support services, adaptive assessment, and data-driven student feedback. It further examines GAI's contribution to constructing intelligent and interconnected teaching ecosystems, strengthening personalized learning pathways, and improving instructional efficiency across diverse disciplinary contexts. Building on an extensive literature-based examination, the study introduces a comprehensive four-dimensional, drive-oriented framework for promoting intelligent university teaching reform-Technology Support, Scenario Integration, Intelligent Feedback, and Competency Development-emphasizing how these dimensions interact to optimize pedagogical decisions, cultivate learner autonomy, and support evidence-based instructional improvement. The proposed framework aims to provide a theoretical foundation and actionable guidance for universities seeking to achieve sustainable, high-quality educational digital transformation in the evolving landscape of the new era.

Keywords: generative artificial intelligence; higher education; intelligent teaching; personalized learning; instructional innovation; digital transformation

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1. Introduction

Contemporary higher education is experiencing a profound transformation, shifting from a focus on informatization toward intelligentization. The rapid development and widespread adoption of generative artificial intelligence (GAI) technologies, including systems such as ChatGPT, DeepSeek, Wenxin Yiyan, Doubao, and Kimi, are fundamentally reshaping the relationship between humans and intelligent agents within educational contexts. In this evolving human-AI teaching ecology, the role of AI is moving beyond mere assistance to active collaboration and co-creation, signaling a new phase in pedagogical reform that emphasizes interactive, adaptive, and data-driven learning environments.

National educational policies increasingly recognize the importance of this transition. For example, strategic plans emphasize the construction of AI-driven intelligent education systems that integrate generative AI into curriculum design, instructional resource development, and evaluation mechanisms [1]. The application of GAI in higher education has the potential to transform a wide spectrum of teaching and learning practices, encompassing personalized learning, adaptive assessment, intelligent tutoring, and data-informed instructional planning [2].

Despite early experimentation in universities with GAI-based teaching assistants and intelligent assessment platforms, most implementations remain limited to auxiliary functions, lacking systematic, context-aware, and closed-loop models that can support

comprehensive intelligent teaching reform. This situation raises critical questions regarding how generative AI can genuinely empower educational transformation and how a scientifically grounded and operationally effective pathway for intelligent reform can be established.

To address these challenges, this study systematically reviews existing research and practice both domestically and internationally and proposes a four-dimensional model for GAI-empowered higher education reform. This framework emphasizes four interconnected dimensions: Technology Support, Scenario Integration, Intelligent Feedback, and Competency Development. Through detailed case analyses and practical examination, the study demonstrates the feasibility and effectiveness of this model, highlighting how GAI can provide systemic empowerment, enhance personalized instructional quality, and enable continuous optimization in higher education teaching practices.

2. Literature Review

2.1. Research Progress of Generative Artificial Intelligence in Education

Generative Artificial Intelligence (GAI) is defined as "an artificial intelligence technology that learns representations of artifacts from data and uses them to generate unique content-such as images, videos, music, speech, and text-that resemble the original data" [3]. A representative example is ChatGPT, which can generate interactive conversational content, demonstrating the potential of large-scale models to achieve knowledge reorganization and creative output across multiple modalities, including text, code, and images [4].

Between 2022 and 2023, research and practical applications of GAI in education have grown rapidly, reflecting its transformative potential for teaching and learning. Policy frameworks and guidance from international organizations emphasize that the adoption of GAI should follow a human-centered approach to ensure responsible, ethical, and inclusive usage. For example, UNESCO has issued policy guidelines advocating equitable and safe integration of generative AI in educational settings. Systematic literature reviews indicate that from 2023 to 2024, empirical studies and review articles on GAI and ChatGPT in higher education have surged, with research topics evolving from feasibility studies to in-depth analyses of curriculum reconstruction, innovative assessment strategies, and learning analytics [5].

GAI has been shown to enhance educational efficiency by reducing the cost and time associated with course material development while improving lesson preparation and instructional planning [6]. In addition, GAI facilitates the transformation of teacher roles, enabling more intelligent and responsive learning support, and fostering the emergence of human-machine-integrated teaching ecosystems that support interactive, adaptive, and personalized learning [7,8]. This shift lays the foundation for a new educational paradigm in which AI-driven agents actively collaborate with instructors and learners to co-create knowledge environments.

2.2. Current Status of Teaching Reform in Chinese Higher Education

In recent years, China has accelerated its policy agenda and top-level planning for educational digitalization, particularly emphasizing the integration of GAI into higher education. Under national strategic guidance, universities have moved from a cautious, wait-and-see approach to an iterative model of "pilot implementation-standardization-promotion." Institutions are encouraged to experiment with GAI-driven teaching innovations while simultaneously developing regulatory frameworks, safeguarding data security, and enhancing AI literacy among faculty and students.

Many "Double First-Class" and regional universities have initiated GAI pilot projects across a variety of disciplines, ranging from general education to engineering practice courses. Applications include virtual teaching assistants, content generation, simulation-

based experiments, and automated code generation [9]. Most pilots follow a hybrid "teacher-led + AI-assisted" model, progressively forming a closed-loop process that integrates teacher review, AI generation, and student validation, thereby fostering continuous feedback and iterative improvement.

The National Smart Education Public Service Platform, led by the Ministry of Education, has incorporated GAI capabilities into its updated framework, emphasizing the integration of universal AI services with localized large models to expand access to intelligent educational resources. Traditional teaching reform in Chinese higher education historically focused on pedagogical philosophy, curriculum design, and teaching methodology. In the current era of intelligentization, technological elements have become critical factors shaping teaching outcomes. Many universities have implemented AI-empowered curriculum pilots in areas such as New Engineering and New Liberal Arts.

Despite these advances, three major challenges persist: technological fragmentation and lack of systematic integration, insufficient AI literacy among instructors, and outdated evaluation systems that lag behind technological innovation [10]. Consequently, constructing a comprehensive and sustainable pathway for intelligent teaching reform based on generative AI has become a central focus for educational research and practical implementation in China.

3. Research Design

Currently, the most widespread application of Generative Artificial Intelligence (GAI) in Chinese higher education is in the automated generation of teaching resources. This includes the creation of lecture notes, exercises and solutions, PowerPoint slides, experimental protocols, programming templates, and case libraries. Studies have shown that GAI can substantially reduce teachers' lesson preparation time while increasing the variety and adaptability of instructional materials [11]. At the same time, research highlights that AI-generated content requires careful verification by instructors to prevent the dissemination of errors or "hallucinations" produced by the models [12].

Another major research focus examines how GAI reshapes classroom interaction and instructional design, supporting pedagogical approaches such as the flipped classroom, problem-based learning (PBL), and project-based learning (PJBL) [13]. AI can function as a "virtual teaching assistant," providing real-time question-and-answer support, scenario simulations, and discussion prompts during lessons. Such capabilities allow teachers to focus on higher-order instructional design, mentoring, and cognitive guidance rather than routine, repetitive tasks. However, studies also emphasize the need to evaluate the reliability, safety, and discipline-specific suitability of AI in highly specialized and practice-oriented courses [14].

A third research direction involves personalized learning. By analyzing learning logs, assignments, and interaction records, GAI can generate tailored exercises, explanations, and learning recommendations for individual students, enhancing learner autonomy and metacognitive development. Empirical evidence suggests that students receiving real-time feedback from GAI often demonstrate higher task efficiency and more positive engagement, though these outcomes are context-dependent and influenced by variables such as task type, prompt quality, and individual metacognitive abilities [15].

Additionally, GAI has been explored for open-ended assessment, automated code review, and formative feedback. Large language models can interpret short-answer responses, abstracts, and programming outputs at a semantic level, offering initial scoring and improvement suggestions, which can alleviate teachers' repetitive grading workload [16]. Nonetheless, concerns remain regarding the reliability, transparency, and explainability of AI-assisted evaluation, leading scholars to recommend that AI-based scoring be complemented with human assessment to maintain academic rigor and fairness [17].

In this study, the objective is to construct an intelligent teaching reform pathway model centered on GAI in higher education. The primary aim is to analyze how GAI empowers teaching reform in universities and to identify the key stages in the process of intelligent reform. A mixed-methods approach, combining literature analysis and case studies, is employed. Representative cases of university curriculum reform are selected to examine the theoretical underpinnings of AI-enabled education. Based on these insights, a four-dimensional model for intelligent reform is developed, encompassing Technology Support, Scenario Integration, Intelligent Feedback, and Capability Cultivation [18].

Following a theory-to-model research logic, this framework integrates conceptual analysis, empirical evidence, and model construction. The overall research structure, illustrating the relationship between theoretical foundations, case evidence, and model development, is presented in Figure 1.

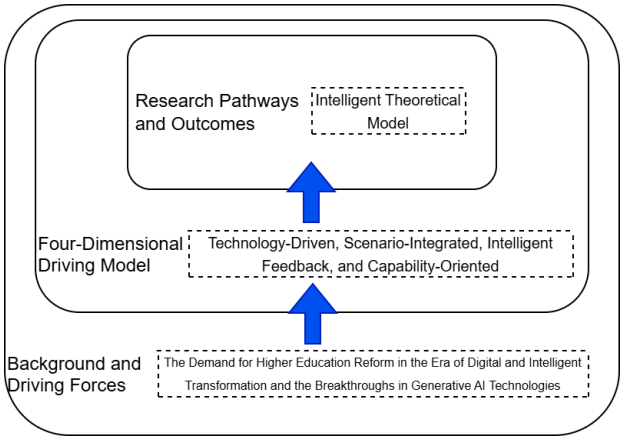

Figure 1. Research Framework of Generative AI Empowerment in Higher Education Teaching Reform.

4. Computer Code Intelligent Reform Pathway Model of Generative AI Empowerment in Higher Education

The intelligent reform process of GAI-empowered higher education can be divided into three progressive stages. In the initial digitalization stage, teaching resources, course content, and process data are managed digitally, primarily relying on instructors' experience and basic information technology. In the intelligentization stage, the introduction of Generative Artificial Intelligence (GAI) enables the automated generation of teaching content, assessment, and feedback, thereby improving instructional efficiency, personalization, and adaptability [19]. Finally, in the human-AI ecological integration stage, a collaborative and self-evolving intelligent teaching ecosystem is established, characterized by human-machine synergy and adaptive learning. Across these three ascending stages, GAI functions as a core enabler, driving both intelligentization and ecological integration in university teaching. Studying the intelligent reform pathway of GAI empowerment thus holds significant theoretical and practical value.

Building upon the theoretical foundations of AI-empowered education, this study constructs a four-dimensional intelligent teaching reform model for higher education, comprising the following core components:

GAI Technology-Driven Layer: Provides algorithmic, model, and data support through GAI, enabling automated content generation and task decomposition.

GAI Teaching Scenario Integration Layer: Embeds GAI into curriculum design, classroom instruction, and learning support to facilitate human-machine co-creation and interactive teaching.

Intelligent Feedback and Optimization Layer: Utilizes learning analytics and data mining to achieve dynamic instructional optimization, personalized guidance, and adaptive evaluation.

Student Capability Cultivation Layer: Enhances students' AI literacy, data thinking, and innovative skills, which in turn reinforces the technology-driven, scenario integration, and intelligent feedback layers.

Through the mutual reinforcement among these four layers, a closed-loop system is formed, enabling continuous improvement and sustainable development in GAI-empowered higher education reform [20].

As illustrated in Figure 2, the proposed model-"Technology-Driven - Scenario-Integrated - Intelligent Feedback - Capability-Oriented"-positions GAI as the central engine, forming a dynamic system composed of technological support, scenario integration, intelligent feedback, and capability cultivation. The model aims to realize the intelligentization, systematization, and sustainable evolution of higher education reform.

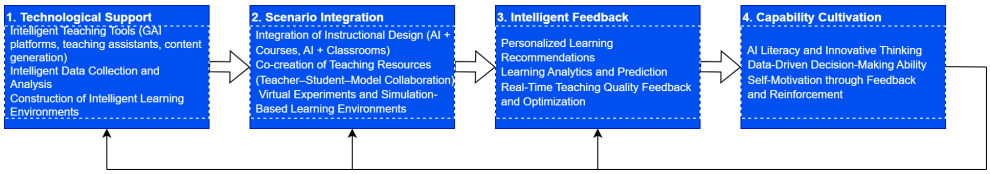

Figure 2. Intelligent Reform Pathway Model of Higher Education Empowered by Generative Artificial Intelligence.

(1) GAI Technology-Support Layer

This layer serves as the primary driving force of the model. By providing algorithms, models, and data through GAI, it enables the intelligent generation of instructional content and automated decomposition of teaching tasks. Key applications include teaching resource development, intelligent lesson preparation, automated Q&A, and assignment grading. Implementation of this layer marks a transformation from traditional manual teaching to intelligent collaborative teaching, providing both the computational engine and technical foundation for innovation in higher education.

(2) GAI Teaching Scenario-Integration Layer

This layer emphasizes the integration of GAI within teaching scenarios. By embedding GAI into curriculum design, classroom instruction, and learning support, instructors and students can collaboratively generate instructional resources and optimize classroom interaction. The integration layer fosters personalized and adaptive teaching activities, promoting the formation of a "human-AI co-teaching and collaborative learning" intelligent classroom ecosystem.

(3) Intelligent Feedback and Optimization Layer

This layer employs Learning Analytics (LA) and Educational Data Mining (EDM) to monitor teaching processes and learning behaviors in real time. The system can automatically generate learning reports and improvement suggestions based on students' learning trajectories and knowledge mastery. Acting as the regulatory mechanism of the model, this layer establishes a "data-driven - feedback-optimized - intelligent-decision" closed loop for continuous teaching improvement, enabling evidence-based instructional adjustments and personalized learning support.

(4) Student Capability-Cultivation Layer

This layer represents both the ultimate goal and an internal driving force of the model. By embedding GAI technologies throughout the teaching process, it systematically enhances students' AI literacy, data thinking, and innovation abilities, facilitating their transformation from "knowledge receivers" to "intelligent creators." Student capability cultivation not only constitutes the output of the model but also reinforces the other three layers:

1) Improved AI literacy strengthens engagement with technology, enhancing the technology-support layer.
2) Increased creativity and learning competence promote active participation in content co-creation and learning environment optimization, reinforcing the scenario-integration layer.
3) Enhanced data awareness and self-regulation capabilities enable more accurate feedback and efficient learning analytics, improving the intelligent-feedback layer.

Thus, the capability-cultivation layer functions simultaneously as the goal of teaching reform and as the endogenous momentum driving model evolution, forming a self-adaptive closed-loop system of "Technology - Teaching - Feedback - Capability." This structure facilitates the continuous evolution and intelligent enhancement of GAI-empowered higher education reform.

The overall operational logic of the model demonstrates a bi-directional cycle of driving and feedback. The technology-support layer provides the intelligent foundation; the scenario-integration layer enables pedagogical implementation; the intelligent-feedback layer ensures ongoing optimization; and the capability-cultivation layer embodies learning outcomes while feeding back into preceding processes. Collectively, these four interlinked dimensions establish a dynamic mechanism of continuous reinforcement and cyclical advancement, ultimately achieving systematic, intelligent, and efficient university teaching reform under the empowerment of generative AI.

5. Conclusion and Implications

Generative Artificial Intelligence (GAI) fundamentally transforms both the modes and boundaries of knowledge transmission, providing a new driving force for higher education reform. The "Technology Support - Scenario Integration - Intelligent Feedback - Capability Cultivation" pathway model proposed in this study offers a comprehensive and feasible framework for constructing an intelligent ecosystem in university teaching, enabling the systematic integration of technology, pedagogy, and learner development.

The findings indicate that GAI functions not merely as a technological tool but as a catalyst for holistic educational innovation. It enables universities to reconceptualize teaching and learning processes, promoting a shift from traditional, instructor-centered approaches to dynamic, interactive, and adaptive educational environments. In this evolving learning context, university instructors are encouraged to transition from the role of "knowledge transmitters" to that of "intelligent facilitators," guiding students in co-creating knowledge, navigating personalized learning pathways, and developing higher-order cognitive and creative skills.

At the institutional level, universities can leverage GAI to foster synergy across teaching resources, assessment mechanisms, and feedback loops. The deployment of GAI-based teaching support platforms allows for the intelligent generation of instructional materials, real-time learning analytics, and adaptive feedback, contributing to enhanced instructional efficiency, personalized learning experiences, and evidence-based pedagogical decision-making. This integration facilitates the creation of a responsive and sustainable intelligent teaching ecosystem where human-AI collaboration is optimized and learning outcomes are continuously refined.

From a policy perspective, educational authorities and governing bodies can support the sustainable development of intelligent teaching reform by establishing robust ethical frameworks, data governance policies, and quality assurance standards for GAI applications in higher education. Emphasis should be placed on transparency, fairness, inclusivity, and the protection of student privacy, ensuring that the deployment of AI technologies aligns with pedagogical objectives and societal expectations.

Future research should explore deeper integration mechanisms of GAI across interdisciplinary and transdisciplinary courses, focusing on scalable, flexible, and context-

sensitive strategies. Additionally, attention should be given to constructing a more open, trustworthy, and equitable intelligent education system that balances technological innovation with human-centered pedagogy. Investigations could examine the long-term impacts of GAI on learner autonomy, collaborative problem-solving, and the development of innovation capacities, as well as strategies for enhancing instructors' AI literacy and professional development. By systematically exploring these dimensions, higher education institutions can realize the full potential of GAI, fostering not only technological advancement but also the cultivation of intelligent, adaptable, and creative learners prepared for the challenges of the digital era.

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