

The Application and Development of Artificial Intelligence Technology in Higher Education Teaching

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Abstract

As the core driving force of the new wave of technological revolution, artificial intelligence is profoundly influencing the teaching models and development direction of higher education. Based on a systematic literature review, this paper outlines the development history of artificial intelligence in higher education, covering the evolution from rule-based intelligent tutor systems to deep learning and multimodal interaction. It summarizes its typical applications in personalized learning support, intelligent assessment, virtual teaching environments, educational management, and resource optimization. The research shows that artificial intelligence, through data-driven teaching feedback and resource allocation, has achieved the scaling of personalized learning, dynamic improvement of teaching quality, and deep optimization of learning interactions. It effectively addresses the challenges of traditional education's "one-size-fits-all" approach and single evaluation system. In the future, the application of artificial intelligence in higher education will further progress towards multi-technology collaboration, interdisciplinary integration, and deep restructuring of educational equity, while facing challenges related to data privacy, algorithmic bias, and ethical standards. This paper argues that the value of artificial intelligence lies not only in technological empowerment but also in promoting the transformation of higher education towards a "fair and high-quality" direction, providing important support for cultivating innovative and critically thinking interdisciplinary talents.

Keywords

Artificial Intelligence; Higher Education; Personalized Learning; Virtual Teaching.

1. Introduction

As an important driving force of the new wave of technological revolution, artificial intelligence is widely penetrating various sectors of society with characteristics such as intelligence, automation, personalization, and collaboration. Higher education, as the core battlefield for talent development, is becoming a key arena for the application of artificial intelligence technology. How to use artificial intelligence to optimize teaching models, improve educational quality, and promote educational equity has become an important issue that urgently needs to be explored.

2. The Development of Artificial Intelligence in Higher Education

The application of artificial intelligence (AI) in the field of education has evolved through multiple stages, driven by technological advancements and the changing needs of education. From the 1970s to the 1990s, it was a period of initial exploration, focusing on the construction of foundational frameworks. In 1970, [1] the SCHOLAR system realized a bidirectional question-and-answer interaction between teachers and students. Although it couldn't sustain ongoing dialogue, it opened the idea of "computers as teaching partners." In 1978, [2] the BUGGY system developed by Brown and Burton used an "error database" to identify procedural errors in arithmetic operations, laying the groundwork for diagnostic teaching based on learner models. In the 1980s, [3] Anderson and others proposed the "model tracing" paradigm, using production rules to simulate the problem-solving process of students. This promoted the development of cognitive tutor systems, making intelligent teaching in structured domains like mathematics and programming possible. The "domain model - tutor model - learner model" triadic architecture was established, which provided a core framework for future intelligent tutoring systems (ITS).

From the early 2000s to the early 2010s was a period of technological iteration, where breakthroughs in machine learning technology expanded application scenarios. In 2003, the ASSISTments platform combined "assisted learning" and "assessment" functions. Teachers could create assignments with hints and scaffolded questions, allowing students to receive immediate feedback, improving math learning efficiency by 0.6 standard deviations. Advances in natural language processing spurred the development of automated assessment, with the SpeechRater engine from the Educational Testing Service (ETS) achieving a correlation of 0.86 with human scoring in TOEFL speaking tests, supporting large-scale language testing. In 2006, Hinton proposed a deep learning solution that solved the "gradient vanishing" problem in neural networks. In 2011, Microsoft applied deep learning to speech recognition, promoting the use of intelligent speech teaching tools. Educational data mining techniques also emerged, predicting student dropout risks with an accuracy of over 81%.

From the mid-2010s to the present is the period of integrated applications, where AI and education are deeply interconnected. In 2016, [4] Google AlphaGo defeating human chess players accelerated the integration of AI into education. The application scenarios during this stage have diversified, with adaptive learning systems like ASSISTments' "Skill Builder" improving knowledge retention by 40% through continuous mastery standards and spaced repetition mechanisms. [5] Virtual simulation labs, combined with VR technology, provide a safe and cost-effective practical environment for engineering and medical disciplines. For example, learners' skill transfer rates in virtual nuclear plant operations were 30% higher than traditional methods. Intelligent collaboration support has become a research hotspot, where AI dynamically groups students to promote complementary learning or summarizes online discussion content to remind teachers to intervene. Affective computing technology can recognize student confusion or boredom, adjusting teaching strategies in real-time. One smart classroom system has used this to improve classroom participation by 25%. In China, iFlytek's English listening and speaking assessment system is used in the national CET-4 and CET-6 exams, and the Mandarin evaluation system covers over 90% of examination sites. The "Next Generation AI Development Plan" in 2017 drove policy exploration for AI in education.

Overall, the application of artificial intelligence in education has always focused on "enhancing personalized teaching efficiency," progressing from rule-based diagnostics to data-driven recommendations and multi-modal intelligent interactions, constantly expanding the boundaries of education. [2] As Luckin and others have stated, this is not only a technological innovation but also a rethinking of the "essence of teaching and learning." Its value lies in

empowering education through technology, enabling more equitable, efficient, and learner-centered education.

3. The Application of Artificial Intelligence in Higher Education

3.1. Personalized Learning Support and Adaptive Teaching

The core advantage of artificial intelligence (AI) lies in achieving "scalable personalization," a characteristic that is fully reflected in higher education teaching practices. Intelligent tutoring systems (ITS) use a triadic architecture—domain model, tutor model, and learner model—to simulate a one-on-one tutoring scenario, as shown in Figure 1. The domain model constructs a subject knowledge network (e.g., the functional relationships in mathematics or causal chains in historical events), the tutor model dynamically adjusts content delivery based on teaching strategies, and the learner model records students' cognitive levels, learning styles, and emotional states. For example, the iTalk2Learn system analyzes learners' understanding of mathematical concepts and cognitive needs, providing tiered hints for fraction learning, which results in a more than 30% improvement in learning efficiency for students of varying levels.

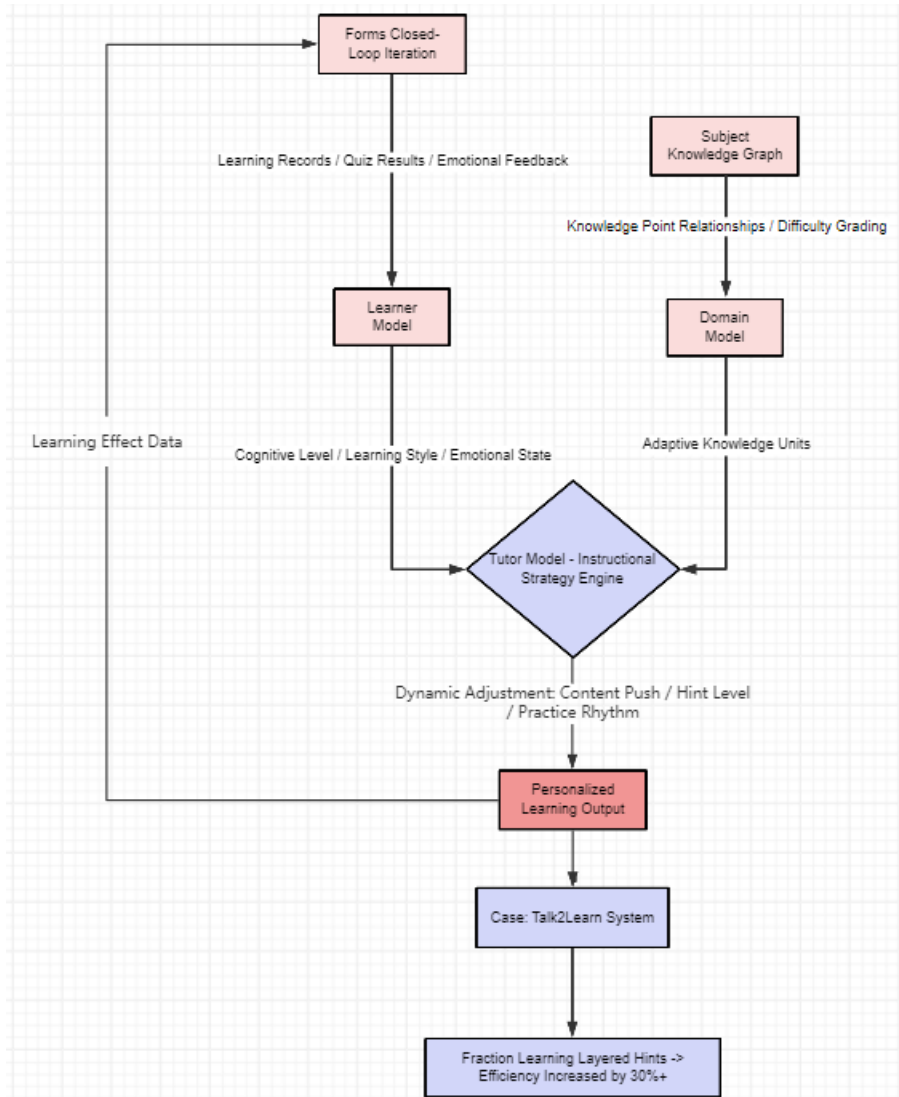


Figure 1. The Triadic Architecture of Intelligent Tutoring Systems (ITS) and the Personalized Learning Process

Adaptive learning platforms further expand the boundaries of personalization. The ASSISTments platform's "Skill Builder" function allows students to practice specific knowledge

points until they meet the mastery criterion of three consecutive correct answers. The “Automated Reassessment and Relearning System (ARRS)” schedules spaced practice sessions at 7, 14, 28, and 60-day intervals, significantly improving knowledge retention. [5] In Massive Open Online Courses (MOOCs), recommendation algorithms, based on learner data such as video watching time and quiz scores, accurately push supplementary materials, increasing course completion rates by 25%. These systems break away from the “one-size-fits-all” teaching model, allowing students to explore knowledge at their own pace, which is especially beneficial for adult learners and those in professional education.

3.2. Intelligent Assessment and Teaching Quality Enhancement

Artificial intelligence has reshaped the educational evaluation system, shifting from “single-result assessment” to “dynamic feedback throughout the learning process.” In automated assessment, systems supported by natural language processing (NLP) can analyze multimodal answers such as text and speech. For instance, the SpeechRater engine developed by ETS achieved a correlation of 0.86 with human judgments in TOEFL speaking evaluation. Similarly, iFlytek’s English listening and speaking assessment system has been applied in China’s CET-4 and CET-6 university exams, providing objective scoring through semantic understanding and pronunciation recognition. In programming education, AI systems can automatically detect logical errors in code and generate suggestions for modification, such as identifying “improper loop condition settings” and guiding students toward debugging directions.

Multidimensional teaching analytics provide precise evidence for instructional improvement. [6] Smart classroom systems leverage computer vision to capture students’ facial expressions (e.g., confusion, concentration, distraction) and eye movements, generating reports on classroom engagement. For example, when 80% of students show frowning expressions, the system alerts the instructor to slow down the pace of explanation. Moreover, by analyzing the distribution of errors in assignments, [5] AI can generate knowledge mastery heatmaps. In one case, a university mathematics instructor increased the teaching hours for the “Differential Equations” chapter by 20% based on system feedback, which raised the student pass rate from 65% to 82%. Such data-driven instructional adjustments enable teachers to reinforce weak areas more effectively, thereby improving overall teaching quality.

3.3. Virtual Teaching Environments and Collaborative Learning Support

The integration of artificial intelligence (AI) with virtual reality (VR) and augmented reality (AR) has created immersive learning environments that transcend the spatial and temporal limitations of traditional teaching. In engineering education, virtual simulation laboratories can replicate high-risk or high-cost experiments, such as nuclear power plant operations or bridge stress analysis. Students explore the impact of parameter changes through interactive operations, while intelligent agents provide real-time corrections for erroneous steps. In medical education, VR-based anatomy systems can present three-dimensional visualizations of human organs. [7] Students interactively “peel away” tissue layers using gesture control, while AI synchronously explains anatomical knowledge points, enhancing practical skills by 40%.

In terms of collaborative learning, AI enhances team effectiveness through dynamic grouping and process support. Intelligent grouping algorithms based on learner models can assemble students with different cognitive levels or disciplinary strengths to foster complementary learning. For example, in business case discussions, the system balances members with strong analytical skills and those with strong communication abilities, improving group report quality by 15%. For online collaboration, natural language processing (NLP) techniques can summarize discussion content, identify off-topic conversations and alert instructors to intervene, or automatically generate summaries of viewpoints, helping groups stay focused on core issues.

3.4. Educational Management and Resource Optimization

The application of artificial intelligence (AI) in higher education management enhances decision-making efficiency and resource utilization. In student management, machine learning algorithms can predict dropout risks by analyzing historical data such as grades, attendance, and extracurricular participation. [1] At one U.S. university, a predictive model achieved an accuracy of 81.2% in identifying high-risk students, leading to a 20% increase in retention rates after targeted interventions. In the admissions process, AI systems integrate multidimensional data—including academic performance, competition experience, and interview results—to optimize admission decisions and reduce human bias.

The development of smart campuses demonstrates the comprehensive management value of AI. [5] Through facial recognition, universities can enable card-free access to dormitories and libraries, while Internet of Things (IoT) sensors regulate classroom temperature, humidity, and lighting, reducing energy consumption by 15%. In resource allocation, AI can forecast student enrollment numbers across different majors, allowing for proactive adjustments in faculty assignments and classroom availability. These applications not only improve administrative efficiency but also align educational resources more precisely with student needs.

4. Advantages of Artificial Intelligence in Higher Education

4.1. Promote the Scale Implementation of Personalized Learning

Artificial intelligence can tailor learning content and pathways based on students' learning styles, cognitive levels, and progress. [8] By continuously tracking learning behavior data—such as answer patterns, error types, and knowledge mastery levels—intelligent systems dynamically adjust the delivery of learning resources, ensuring that students with different foundations receive appropriate support. Whether providing step-by-step scaffolding for students with weaker foundations or offering advanced content for high achievers, AI enables truly individualized instruction. This effectively addresses the limitations of traditional “one-size-fits-all” teaching, which struggles to accommodate individual differences.

4.2. Optimizing Teaching Evaluation and Feedback Mechanism

AI has revolutionized traditional educational evaluation models by shifting from “summative assessment” to “formative assessment.” Intelligent systems can analyze and provide feedback on students' performance across assignments, quizzes, and classroom interactions in real time. They not only complete automated grading efficiently, reducing teachers' workload, but also accurately identify students' weak areas in knowledge acquisition. Furthermore, through in-depth analysis of evaluation data, AI systems generate detailed learning reports that help teachers adjust instructional strategies in a timely and targeted manner, thereby improving overall teaching effectiveness.

4.3. Enhancing Student Engagement and Interaction Quality

AI enhances students' sense of participation in the learning process through various technological means. By leveraging data analytics, systems can identify students' learning states—what has been mastered and what remains confusing—enabling teachers to design activities that better meet learners' needs. During classroom interactions, [9] intelligent systems can support different types of students, including those less expressive, by offering targeted guidance and encouragement. This ensures that all students actively participate in discussions and practices, creating a more dynamic and effective learning environment.

4.4. Supporting Course Design and Teaching Innovation

AI provides teachers with data-driven insights and inspiration for course design. By analyzing student learning data, systems can predict potential learning difficulties and assist teachers in

refining course content and instructional plans. Additionally, intelligent systems can construct adaptive learning environments that deliver instant feedback and support—for example, automatically detecting errors and offering corrective suggestions—allowing students to continuously refine their knowledge through practice. This data-informed approach ensures the scientific rigor of instruction while leaving space for pedagogical innovation.

5. Future Development of Artificial Intelligence in Higher Education

The integration of artificial intelligence (AI) with higher education is moving from localized applications toward systemic reconstruction, [10] with future development expected to be multidimensional and profound. Single-function intelligent tools will gradually merge into multi-technology collaborative ecosystems, and the deep integration of natural language processing, computer vision, affective computing, and virtual reality will create more immersive and interactive learning environments. For example, virtual classrooms will not only simulate real teaching scenarios but also adjust instructional strategies in real time by capturing students' micro-expressions and vocal intonations, making remote learning experiences nearly equivalent to face-to-face instruction. Adaptive learning systems will become increasingly refined, dynamically optimizing content difficulty and presentation based on learners' cognitive load, attention fluctuations, and other real-time data, achieving true "personalized learning for every individual." AI will drive higher education from "knowledge transmission" toward "competency cultivation." Intelligent systems can handle foundational knowledge instruction and assessment, freeing teachers to focus on developing critical thinking, creativity, and ethical awareness. In STEM education, AI may automatically perform formula derivations or demonstrate experimental procedures, while teachers guide students in project-based learning around complex engineering problems, fostering interdisciplinary problem-solving skills. Interdisciplinary learning will become the norm, with AI analyzing the intrinsic connections between different domains to recommend customized cross-disciplinary learning paths, such as linking ethics courses to computer science students to explore the ethical boundaries of AI and cultivate versatile, well-rounded talent.

The advancement of educational equity will enter a new stage, with artificial intelligence not only democratizing access to resources but also striving for equal opportunities. [11] Students in remote areas can access high-quality courses through smart devices, while virtual teaching assistants provide personalized guidance comparable to that of top-tier institutions. [12] For students with special educational needs, AI will develop more inclusive tools, such as voice-interactive textbooks for visually impaired learners and real-time sign language translation systems for hearing-impaired students. At the same time, technological applications will place greater emphasis on cultural adaptability, customizing localized content according to regional educational traditions to avoid a "one-size-fits-all" approach and truly achieve "equitable and high-quality" education. As AI adoption deepens, ethical standards and risk management will become critical concerns. Robust data privacy protection mechanisms will be established, clearly defining the boundaries and rules for collecting and using learning data to prevent privacy breaches. To mitigate educational inequities potentially caused by algorithmic bias, more inclusive algorithm designs will be developed, incorporating diverse evaluation metrics and respecting individual differences. Universities will also strengthen AI ethics education, integrating ethical discussions into both professional and general courses, guiding faculty and students to consider the boundaries and humanistic value of technology, and ensuring that AI serves the holistic development of individuals.

Ultimately, the future development of artificial intelligence in higher education will form a collaborative innovation ecosystem involving universities, enterprises, government, and society. Universities will work with technology companies to develop education-focused

solutions, enterprises will provide practical application scenarios, governments will guide and regulate development through policies, and societal stakeholders will participate in evaluation and oversight. Together, this ecosystem will promote the open sharing of resources and the dynamic adjustment of talent cultivation programs. It will facilitate cross-institutional resource co-construction and establish real-time feedback mechanisms between talent demand and educational programs, enabling higher education to align more precisely with societal development needs and ultimately achieving the core goal of cultivating future talents with innovation, critical thinking, and humanistic literacy.

6. Conclusion

This article systematically expounds the application and development of artificial intelligence technology in higher education teaching, aiming to explore how technological empowerment can address the challenges of traditional education and promote the transformation of teaching models toward personalization and intelligence. By examining its developmental trajectory and typical applications, it is evident that AI, through tools such as intelligent tutoring systems and adaptive learning platforms, enables large-scale individualized instruction and fine-grained dynamic adjustments to the teaching process. At the same time, in areas such as intelligent assessment, virtual simulation, and educational management, AI has effectively improved teaching quality, resource utilization, and learning experiences. These applications not only highlight the value of technological enhancement but also reflect a deeper reconsideration of the essence of teaching and learning.

However, this research is mainly based on a literature review, and thus the breadth and depth of empirical data are limited, especially regarding cross-cultural adaptability and attention to special education groups. The future development of AI in education requires achieving multimodal integration and ecological collaboration at the technical level, in order to build more immersive and adaptive learning environments. At the ethical level, it is necessary to establish sound data privacy and algorithmic fairness standards to mitigate potential risks. Looking ahead, greater emphasis should be placed on interdisciplinary collaboration and long-term effectiveness evaluation, thereby advancing AI applications in education from auxiliary tools toward systemic reconstruction. Ultimately, this will help build a more equitable, inclusive, and efficient higher education ecosystem that fosters holistic human development and sustainable social progress.

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