

Applied Research and Practice of Artificial Intelligence in University Physics Courses

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Abstract: *Physics is the foundation of the natural sciences, and its disciplinary ideas and methods have played a significant guiding role in the origins and development of artificial intelligence (AI). In order to better grasp the development trends of frontier technologies and closely follow the pulse of the times, this paper centers on three core scenarios—teaching, learning, and assessment—in university physics courses with regard to artificial intelligence, and builds an AI-driven framework for curriculum reform. The application of artificial intelligence technology can enhance students' understanding of abstract physics concepts and their experimental operation skills, increase learning motivation, reduce teachers' repetitive workload, and promote the intelligent and equitable development of higher education physics. This paper also analyzes the challenges faced by AI in university physics teaching and looks ahead to future development trends, aiming to provide theoretical references and practical guidance for the reform of university physics teaching.*

Keywords: *artificial intelligence, university physics courses, three core scenarios, teaching reform; personalized learning*

1. Introduction

In the current era of rapid development of information technology, artificial intelligence is gradually penetrating into various fields, especially the field of education^[1]. As an important foundational course for science and engineering majors, university physics bears the significant mission of cultivating students' scientific thinking, logical reasoning abilities, and innovative consciousness. Physics not only provides the theoretical foundation for the development of artificial intelligence, but its disciplinary ideas and methods have also profoundly influenced the evolution of artificial intelligence. However, current university physics teaching faces numerous challenges: students have widely varying foundations, making it difficult to teach according to their individual aptitudes; physics concepts are abstract and difficult to understand; teaching feedback is delayed, making precise guidance difficult to achieve; and experimental teaching is limited, resulting in insufficient depth of inquiry^[2, 3]. These issues not only affect students' learning outcomes but also constrain the improvement of teaching quality.

Applying artificial intelligence technology to university physics teaching can not only revolutionize the way physics knowledge is imparted but also inject new vitality into application-oriented undergraduate education^[4]. Therefore, this paper focuses on the three core scenarios of "teaching," "learning," and "assessment" in university physics courses with respect to artificial intelligence, constructing an AI-driven curriculum reform framework, aiming to provide references for improving the quality of university physics teaching and addressing practical problems in current instruction. Accordingly, this paper systematically explores the paths and mechanisms of AI-enabled university physics teaching around the three core scenarios of "teaching," "learning," and "assessment," constructs an AI-driven curriculum reform framework, and enriches the theoretical system of integrating information technology with physics curricula.

2. The Importance of AI-Enabled University Physics Teaching

2.1. Optimizing the Allocation of Teaching Resources

In university physics courses, artificial intelligence significantly improves the availability, relevance, and timeliness of teaching resources through learning data analysis, intelligent content generation, and

resource platform construction^[5].

2.1.1. Learning Data Analysis-Driven Resource Recommendation

By mining students' homework, test results, and classroom interaction data, AI systems can identify common difficulties and individual problems among students, and automatically recommend personalized learning materials, exercises, and simulated experiments^[5]. For example, when the system detects that multiple students have made errors in assignments on the chapter of "Electromagnetic Induction," it automatically pushes relevant concept explanation videos and targeted practice questions. For individual students with specific difficulties, the system recommends personalized supplementary learning resources.

2.1.2 Intelligent Content Generation to Assist Lesson Preparation

Teachers can leverage AI technology to refine lecture content, automatically generate practice questions with detailed solution steps, and provide tiered tasks according to students' varying proficiency levels^[6]. AI systems can also transform teachers' lecture notes into multimedia teaching resources, such as automatically generating PowerPoint presentations and creating animated demonstrations of key concepts, significantly improving lesson preparation efficiency.

2.1.3. Resource Platform Construction and Unified Management

With the establishment of centralized resource platforms, schools can achieve unified management, search, and version control of resources such as textbooks, lecture notes, courseware, question banks, and simulated experiments^[7]. Teachers can easily find and use teaching resources, while students can engage in self-directed learning as needed. The construction of resource platforms not only improves resource reuse rates but also accelerates update speed, ensuring the timeliness of teaching content.

2.1.4. Multimedia Resource Integration and Visualization

AI can integrate diverse resources such as text, animations, and virtual experiments to provide more intuitive and interactive learning materials^[7]. For example, AI-driven 3D dynamic models can help students better understand complex concepts such as mechanical vibrations and electromagnetic field distributions. By transforming abstract physical principles into intuitive visual images, AI significantly reduces students' cognitive load.

2.2. Innovative Teaching Approaches

Through artificial intelligence technology, the teaching model of university physics courses has been significantly optimized.

2.2.1. Personalized Learning Path Planning

Using intelligent algorithms, personalized teaching paths can be provided according to students' learning progress. The system analyzes students' learning behavior data to identify their knowledge mastery levels and learning styles, automatically planning the most suitable learning route^[5]. For example, for students with weak foundations, the system guides them to review prerequisite knowledge first; for advanced students, the system pushes extended learning content.

2.2.2. Virtual Simulation Experiments

AI-driven virtual simulation experiments can break the constraints of time and space, allowing students to perform experimental operations in virtual environments and enhance practical skills^[7]. Virtual experiment platforms not only simulate real experimental environments but also allow students to freely adjust parameters and try repeatedly without worrying about equipment damage or safety issues. For example, in "Nuclear Physics Experiment" teaching, virtual simulations can simulate the decay process of radioactive materials, allowing students to observe the motion patterns of microscopic particles.

2.2.3. Intelligent Teaching Platform Applications

Tsinghua University launched the "AI-enabled Teaching Ten-Point Curriculum Work Plan," leveraging the Zhipu Qingyan large language model and the XuetangX online platform to provide technical support for courses such as "University Physics A" and "Fundamental Physics." This initiative explores how AI technology can optimize aspects such as course design, slide development, and classroom instruction, providing a successful case study for the reform of university physics teaching.

2.2.4. Blended Teaching Models

The blended teaching model supported by AI technology combines online learning with offline instruction. Students can watch teaching videos, complete virtual experiments, and participate in online discussions; classroom time is then focused on inquiry-based learning, interactive communication, and deep learning. This teaching model fully leverages the advantages of both online and offline approaches, improving teaching efficiency and learning outcomes.

2.3. Strengthening Interactive Feedback in Teaching

Intelligent teaching platforms can support real-time interaction, allowing students to obtain immediate answers to questions through AI question-answering systems during the learning process^[5].

2.3.1. Intelligent question-answering and Immediate Feedback

AI question-answering systems can answer students' questions, providing immediate feedback^[1]. When students encounter difficulties, they do not need to wait for the teacher's response but can directly ask the AI assistant for timely help. AI systems can not only answer factual questions but also provide problem-solving guidance, concept explanation, and learning suggestions.

2.3.2. Classroom Interaction and Real-Time Assessment

During classroom teaching, teachers can push practice questions at any time, and students answer using their phones or tablets. AI systems instantly calculate response statistics and generate correctness distribution charts, helping teachers understand students' mastery of new knowledge. For questions with high error rates, teachers can provide immediate explanations to address students' confusion.

3. AI in Learning for University Physics Courses

3.1. Personalized Learning

Artificial intelligence technology can provide personalized learning suggestions and resources according to students' learning status and needs^[5, 6].

3.1.1. Learning Diagnosis and Analysis

AI assistants can analyze students' homework data, test scores, and classroom performance to identify their knowledge mastery levels and learning difficulties, providing a basis for teachers to optimize teaching content and methods, while also helping students pursue personalized learning according to their actual circumstances^[7]. The system generates learning status reports, clearly presenting students' strengths and weaknesses.

3.1.2. Personalized Learning Path Planning

Based on learning diagnosis results, AI systems plan optimal learning paths for students. The system recommends appropriate learning sequences and resources based on students' knowledge foundations and learning goals, ensuring that students always learn within their "zone of proximal development^[5]." For concepts that are difficult to understand, the system recommends basic explanation videos and exercises; for content that has been mastered, the system pushes advanced learning materials.

3.1.3. Intelligent Resource Recommendation

AI assistants can also provide services such as retrieving materials and asking follow-up questions to support students in learning more effectively^[7]. The system recommends relevant learning resources based on students' learning history and current needs, including concept explanations, example analyses, extended reading, and cutting-edge research. This personalized recommendation helps students efficiently access needed information, avoiding getting lost in a sea of resources^[8].

3.2. Intelligent Assistive Tools and Resource Integration

Artificial intelligence technology is also applied to virtual physics laboratory simulations in universities, simulating real experimental environments and allowing students to perform experiments in virtual settings^[7].

3.2.1. Virtual Experiment Platforms

Virtual experiment platforms use AI technology to simulate real experimental environments, providing rich experimental resources to help students better understand and master physics concepts and principles. Platforms not only support traditional static operations but also provide real-time data interaction and feedback mechanisms, making the experimental process more vivid and intuitive.

For example, the NOBOOK virtual experiment platform can complete various physics experiments such as electricity, mechanics, and optics. It integrates advanced computer technology, virtual reality technology, and database management systems, achieving in-depth development and refinement of virtual simulation experimental environments. The Labster experiment platform is suitable for university physics teaching, providing students with realistic experimental processes and intelligent feedback.

3.2.2. Intelligent Experiment Assistants

Intelligent experiment assistants, developed using natural language processing and computer vision technologies, can provide experiment explanations to students before experiments, saving teachers significant time while also facilitating the development of students' autonomous learning abilities. During experiments, intelligent assistants collect student experiment data and analyze it after completion, providing teachers with references for understanding students' learning situations.

For example, intelligent assistants can identify step-by-step errors in students' experimental operations and provide timely corrections, while also counting the frequency of errors in each step, guiding teachers' subsequent explanations^[9].

3.2.3. Intelligent Simulation and Modeling

AI technology can also support intelligent simulation and modeling of physical processes. Students can freely adjust parameters and observe system dynamics to explore physical laws. For example, in "Simple Harmonic Motion" teaching, students can adjust parameters such as amplitude, frequency, and damping coefficient to observe changes in vibration curves; in "Electromagnetic Wave Propagation" teaching, students can change frequency and medium parameters to observe changes in wave velocity and wavelength.

4. Assessment of Artificial Intelligence in University Physics Courses

4.1. Intelligent Assessment and Immediate Feedback

Another important application of artificial intelligence technology in university physics courses is intelligent assessment and immediate feedback^[6, 7].

4.1.1. Intelligent Scoring Systems

Through the use of intelligent scoring systems, assignments can be automatically graded, reducing teachers' workload while providing students with immediate feedback to help them promptly understand their learning progress and existing problems. University physics assignments contain a large number of complex formula derivations and numerical calculations. AI systems can not only grade objective questions but also recognize handwritten formulas through OCR, performing logical comparison and intelligent analysis of the solution steps for subjective questions.

4.1.2. Solution Process Analysis

AI systems can identify whether students' problem-solving approaches are correct, pinpoint where errors occur (whether conceptual misunderstandings, calculation mistakes, or logical reasoning problems), and provide targeted hints and suggestions. This process analysis helps students deeply understand their errors and avoid repeating similar mistakes.

4.1.3. Learning Monitoring and Instructional Adjustment

Artificial intelligence technology can also be used to monitor students' learning states, providing teachers with comprehensive learning analysis to guide adjustments to teaching strategies. The system generates overall class learning reports, including information on knowledge point mastery, common error types, and learning progress distribution, providing data support for teachers' instructional decisions.

4.1.4. Immediate Feedback Mechanisms

The immediate feedback mechanism provided by AI systems greatly shortens the feedback cycle. Students receive grading results and evaluation comments immediately after submitting assignments, without waiting for days. This immediate feedback helps students promptly correct errors and consolidate learning outcomes.

4.2. Assessment Design, Fairness, and the Teacher's Role

Artificial intelligence can assist in designing exam questions, scoring rubrics, and peer assessment mechanisms, which is particularly suitable for large-scale courses to achieve standardized scoring and consistent evaluation.

4.2.1. AI-Assisted Question Design

AI systems can automatically generate exam questions based on course objectives and teaching priorities. The system can control question difficulty, discrimination, and knowledge coverage, ensuring the scientific validity and effectiveness of test questions. At the same time, the system can dynamically adjust question difficulty based on students' responses, enabling adaptive testing.

4.2.2 Teacher's Role and Quality Control

However, for complex physical reasoning and innovative problem-solving, AI may produce misjudgments, requiring teachers to check against manual scoring criteria. AI assessments should be auxiliary; final grades remain determined by teachers. Teachers need to exercise professional judgment, reviewing and adjusting AI evaluation results to ensure accuracy.

5. Challenges and Countermeasures

Although the application of artificial intelligence technology in university physics teaching has brought many benefits, it also faces several challenges, such as technological equipment updates, content screening and curation, and the cultivation of students' autonomous learning abilities.

5.1. Main Challenges

5.1.1. Technological Equipment Updates and Costs

The construction and maintenance of AI teaching systems require high hardware investment and technical support. High-performance computing platforms, virtual experiment equipment, and intelligent teaching systems all require funding, placing pressure on schools with limited budgets. At the same time, technology updates rapidly, requiring continuous equipment upgrades and increasing long-term investment costs.

5.1.2. Content Screening and Quality Control

AI-generated teaching content requires quality control. AI systems may generate inaccurate or inappropriate content that requires manual review and screening. At the same time, ensuring that AI-recommended content aligns with teaching objectives and curriculum standards is another concern.

5.1.3. Cultivation of Students' Autonomous Learning Abilities

Some students may become overly dependent on AI tools, lacking the ability and motivation for independent thinking and exploration. Some students treat AI as an "answer machine," asking questions directly without engaging in the thinking process. This phenomenon may affect the development of students' ability to solve problems independently^[10].

5.1.4. Improvement of Teachers' Digital Literacy

Some teachers have difficulty accepting new technologies, struggling to operate intelligent teaching platforms proficiently, leading to AI tools being used superficially without fulfilling their intended roles. Teachers need to master the use of AI systems, understand AI-generated content, and effectively integrate AI tools into teaching practice.

5.1.5. Limitations of AI Systems

Current AI systems still have certain limitations: limited ability to understand open-ended questions;

difficulty identifying students' emotional states and needs; simplifications in simulating complex physical situations that may differ from reality; and suboptimal interaction experiences on some platforms.

5.2. Countermeasures

5.2.1. Strengthen Technological Investment and Resource Sharing

Schools should establish dedicated funds to support the construction and maintenance of AI teaching platforms. At the same time, inter-school collaboration and resource sharing can reduce individual schools' investment costs. Priority should be given to selecting mature and stable platforms and tools to avoid redundant development.

5.2.2. Establish Content Review Mechanisms

Establish review mechanisms for AI-generated content, with teachers responsible for screening AI-recommended content to ensure accuracy and appropriateness. Regularly evaluate AI system performance to promptly identify and resolve issues. At the same time, encourage teachers to participate in the training and optimization of AI systems to improve their professional capability.

5.2.3. Cultivate Students' Autonomous Learning Abilities

Emphasize the auxiliary role of AI in teaching, requiring students to attempt independent thinking before using AI. Increase the proportion of open-ended questions and inquiry-based tasks in teaching design, guiding students to use AI for deep thinking rather than simply obtaining answers. Set aside "AI-free" moments to encourage students to discuss and collaborate to solve problems.

5.2.4. Improve Teachers' Digital Literacy

Establish teacher training mechanisms to regularly conduct "AI+Physics" teaching skills workshops^[10]. Encourage collaboration between young teachers and experienced teachers to jointly develop AI teaching resources suitable for their school's context. Organize teaching observations and experience-sharing activities to help teachers see the practical effects of AI teaching and build confidence in its application.

5.2.5. Leverage Teacher Strengths to Compensate for AI Limitations

Teachers should focus on open-ended questions that AI systems find difficult to handle, transforming them into classroom inquiry resources. For student confusion identified by AI systems, teachers should provide in-depth explanations and guidance. Teachers play an irreplaceable role in emotional communication, value guidance, and innovative thinking cultivation.

6. Development Trends and Prospects

In the new era, the application and practice of artificial intelligence in university physics course teaching will present the following development trends:

6.1. Popularization of Personalized Learning

As artificial intelligence technology continues to advance, personalized learning will become an important trend in future education. More universities will adopt intelligent learning systems, providing customized learning programs based on students' learning characteristics and needs. Adaptive learning technologies will become more mature, able to accurately identify students' learning states and dynamically adjust learning content and difficulty levels. Students will be able to learn at their own pace, achieving true individualized instruction.

6.2. Widespread Application of Virtual Experiments

The maturation of virtual reality and augmented reality technologies will promote the widespread adoption of virtual laboratories. In the future, students will be able to conduct experiments in more richly immersive virtual environments, enhancing practical abilities and innovative thinking. Virtual experiments will be organically combined with physical experiments to form an integrated experimental teaching model. For dangerous, expensive, or difficult-to-implement experiments, virtual experiments will become important alternatives or supplements.

6.3. Data-Driven Teaching Decisions

As educational big data accumulates, data-driven teaching decisions will become more scientific and effective. Teachers will be able to monitor students' learning states through data, promptly adjust teaching strategies, and optimize teaching outcomes. Learning analytics technologies will provide deeper insights into learning situations, helping teachers identify students' learning difficulties and patterns, and implement targeted instructional interventions.

6.4. Deepening Interdisciplinary Integration

The application of artificial intelligence is not limited to physics teaching; it will also be deeply integrated with other disciplines to form interdisciplinary teaching models. This integration will enhance students' overall qualities and cultivate talents with stronger innovative capabilities. For example, the integration of physics and computer science can cultivate computational physics talents; the integration of physics and life sciences can cultivate biophysics talents. Interdisciplinary teaching will help students build more comprehensive knowledge systems.

In summary, research on the application of AI in university physics courses is developing rapidly, and both domestic and international research and practice provide valuable experience and insights. By drawing on advanced international experience and combining it with domestic realities, we can expect to achieve higher-quality educational reform in physics teaching^[6, 8]. Ensure the effective application of artificial intelligence technology in university physics courses, promote educational reform, and enhance teaching quality as well as students' comprehensive abilities.

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