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Practical Research on Optimizing Primary School Science Experiment Teaching with Artificial Intelligence Technology

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Abstract: This study focuses on using artificial intelligence (AI) technology to optimize primary school science experiment teaching. Through an analysis of the current application status of AI in primary school science experiment teaching, it was found that problems such as limited application scope, scarce teaching resources, and insufficient teacher application capabilities exist. Research methods including literature review, questionnaire surveys, and teaching experiments were employed to construct an AI-assisted primary school science experiment teaching model, optimizing various aspects such as experimental design, teaching processes, and evaluation feedback. The results show that the application of AI technology has significantly enhanced students' interest in science experiments, improved their experimental operation skills and scientific inquiry abilities. Meanwhile, teachers have a high level of satisfaction with AI-assisted teaching, though challenges in technical stability and teacher training still require improvement. This study provides valuable practical experience and theoretical support for the innovative development of primary school science experiment teaching.

Keywords: Artificial Intelligence; Primary School Science; Experimental Teaching; Teaching Optimization.

1. Introduction

1.1. Research Background

With the rapid development of technology, artificial intelligence (AI) has gradually penetrated into various fields of society, including education. As a crucial way to cultivate students' scientific literacy and practical abilities, primary school science experiment teaching is facing the need for innovation and transformation. AI technology, with its powerful functions such as data analysis, personalized learning support, and virtual simulation, brings new opportunities to primary school science experiment teaching. It can break through the limitations of traditional experimental teaching in time, space, and resources, providing students with richer, more vivid, and personalized learning experiences[1].

In China, primary school science education has gained increasing attention, and the science curriculum standards emphasize the cultivation of students' scientific inquiry abilities and innovative thinking. However, traditional primary school science experiment teaching faces challenges such as limited experimental resources, single teaching methods, and difficulty in meeting students' individual needs. The introduction of AI technology is expected to address these issues and improve the quality and effectiveness of primary school science experiment teaching. For example, AI-assisted experimental design can make experimental plans more scientific and reasonable; virtual simulation experiments allow students to conduct diverse experimental operations in a safe and convenient environment; intelligent evaluation systems can provide timely and accurate feedback on students' learning, guiding teaching adjustments[2].

1.2. Research Objectives and Significance

1.2.1. Research Objectives

This study aims to deeply explore the application methods and effects of AI technology in primary school science experiment teaching[3]. By constructing an AI-assisted teaching model, it seeks to optimize various links of experimental teaching, including experimental design, operation, and evaluation, so as to improve the quality of science experiment teaching, stimulate students' interest in science experiments, and cultivate their scientific inquiry abilities and innovative thinking. Specific objectives include:

Analyzing the current application status of AI in primary school science experiment teaching to identify existing problems and shortcomings.

Building an optimization model for primary school science experiment teaching based on AI technology, and clarifying implementation strategies for each link.

Verifying the role of AI technology in enhancing the effectiveness of primary school science experiment teaching through empirical research, including changes in students' learning interest, experimental operation skills, and scientific inquiry abilities.

Collecting teachers' feedback on AI-assisted teaching to provide references for further promotion and improvement.

1.2.2. Research Significance

Theoretical Significance: Enriching the theoretical system of primary school science experiment teaching by integrating AI technology with educational theories, and providing new perspectives and ideas for exploring the deep integration of information technology and subject teaching. Meanwhile, it validates and improves relevant theories through analysis of practical data, promoting the development of primary science education theories[4].

Practical Significance: Providing specific AI-assisted teaching methods and strategies for primary school science teachers to help them design and implement science experiment teaching more effectively. Offering decision-making references for schools and educational departments in teaching resource allocation and teacher training, and promoting the informatization construction of primary school science experiment teaching. For students, it helps stimulate learning interest, cultivate practical abilities and innovative spirit, and lay a foundation for their future development.

Social Significance: Promoting the application and popularization of AI technology in basic education and enhancing educational equity. Enabling more students to access high-quality science education resources, cultivating innovative talents adapted to future social development, and contributing to national scientific and technological progress.

2. Research Status and Theoretical Foundations

2.1. Current Application Status of AI in Primary School Science Experiment Teaching

Through field investigations in multiple primary schools, teacher interviews, and literature analysis, it was found that the application of AI in primary school science experiment teaching is still in its infancy. Although some schools have begun to introduce AI technology, its application scope remains narrow, mainly focusing on the following aspects:

Application of Intelligent Teaching Tools: Some schools use intelligent teaching platforms to assist science experiment teaching, which can provide resources such as experimental videos and virtual experiment simulations. For example, an intelligent teaching platform offers virtual simulations of common science experiments like "circuit connection" and "object buoyancy," allowing students to operate and observe phenomena online. However, teachers reported that such platforms are not fully functional, and the authenticity and interactivity of experiment simulations need improvement[5].

Use of Educational Robots: Some schools are equipped with educational robots for science experiment activities such as robot programming. In a robot soccer experiment activity, students controlled robot movements through programming to complete tasks. However, the use of educational robots is limited by venue, equipment quantity, and teachers' professional competence, making it difficult to widely implement in daily science experiment teaching.

Attempts at Intelligent Evaluation Systems: A few schools have introduced intelligent evaluation systems to assess students' experimental reports and operation processes. For instance, an intelligent evaluation system can analyze the scientificity and logic of students' experimental reports and provide feedback and suggestions. However, it still has limitations in real-time evaluation of students' experimental operations and cannot comprehensively and accurately assess their experimental abilities.

Survey data show that only 30% of primary school science teachers frequently use AI technology in experiment teaching, 45% use it occasionally, and 25% have never used it. This indicates that the application of AI in primary school science experiment teaching has not been widely promoted and has significant development potential.

2.2. Theoretical Foundations

2.2.1. Constructivist Learning Theory

Constructivist learning theory posits that learning is an active knowledge construction process for students, who acquire knowledge through meaning construction in specific contexts with the help of teachers, peers, and learning resources. In primary school science experiment teaching, AI technology can create realistic experimental scenarios and provide abundant learning resources to help students better construct scientific knowledge. For example, virtual simulation experiments allow students to observe and operate in immersive environments, building an understanding of scientific concepts through exploration.

2.2.2. Theory of Multiple Intelligences

Proposed by Howard Gardner, the theory of multiple intelligences argues that human intelligence is diverse, including linguistic, logical-mathematical, spatial, bodily-kinesthetic, musical, interpersonal, intrapersonal, and naturalist intelligences. AI technology can provide personalized learning paths and resources based on students' different intelligence characteristics. For example, students with strong spatial intelligence may be recommended more virtual 3D experiments, while those with outstanding logical-mathematical intelligence could receive more challenging experimental data analysis tasks to meet their individual learning needs.

2.2.3. Theory of Information Technology and Curriculum Integration

The theory of information technology and curriculum integration emphasizes organically integrating information technology into curriculum teaching to make it an integral part of teaching, thereby improving teaching efficiency and effectiveness. As a cutting-edge field of information technology, the integration of AI with primary school science experiment teaching can innovate teaching models and optimize teaching processes. Through AI technology, digitalization of experimental teaching resources and intellectualization of teaching processes can be achieved, promoting students' autonomous and inquiry-based learning.

3. Research Design and Methods

3.1. Research Design

This study adopted action research, selecting two parallel classes in a primary school as the research objects, designated as the experimental class and the control class. During the experimental period, the control class used traditional science experiment teaching methods, while the experimental class introduced AI technology for auxiliary teaching. By comparing the performance of students in both classes in terms of experimental interest, operational skills, and scientific inquiry abilities, the optimization effect of AI technology on primary school science experiment teaching was evaluated.

Before the experiment, pre-tests were conducted on students' scientific foundations and learning interests in both classes to ensure similarity at the initial stage. During the experiment, the teaching process of the experimental class was meticulously recorded, including the application of AI technology and students' classroom responses. After the experiment, data were collected through post-tests, questionnaires, and teacher interviews for result analysis.

3.2. Research Methods

3.2.1. Literature Review

Domestic and foreign literature on the application of AI in education, particularly in primary school science experiment teaching, was reviewed to understand research status and trends, providing theoretical support and research ideas for this study. By combing through the literature, the achievements and shortcomings of existing research were summarized to clarify the entry point and innovations of this study.

3.2.2. Questionnaire Survey

Questionnaires were designed for students and teachers. The student questionnaire aimed to understand their interest in science experiments, acceptance of AI-assisted experimental teaching, and learning experiences. The teacher questionnaire focused on teachers' feelings, challenges encountered, and teaching effect evaluations during AI-assisted experiment teaching. Student questionnaires were administered before and after the experiment to compare changes, while teacher questionnaires were conducted after the experiment to collect feedback. A total of 200 student questionnaires were distributed, with 185 valid responses (92.5% valid response rate); 30 teacher questionnaires were distributed, with 28 valid responses (93.3% valid response rate).

3.2.3. Teaching Experiment

According to the research design, AI-assisted science experiment teaching was carried out in the experimental class, while traditional teaching was implemented in the control class. During the experiment, teaching variables were strictly controlled to ensure that conditions such as teaching content, duration, and teacher qualifications were basically consistent between the two classes. Regular knowledge tests and experimental operation assessments were conducted for students in both classes, with scores and performance recorded for subsequent comparative analysis.

3.2.4. Case Analysis

Typical teaching cases from the experimental class were selected for in-depth analysis, including experimental teaching design, details of AI technology application, students' learning processes, and achievements. Through detailed 剖析 (analysis) of cases, application experiences and existing problems of AI technology in primary school science experiment teaching were summarized, providing specific references for teaching optimization.

4. Practice of Optimizing Primary School Science Experiment Teaching with AI Technology

4.1. Constructing an AI-Assisted Primary School Science Experiment Teaching Model

Based on research objectives and theoretical foundations, an AI-assisted primary school science experiment teaching model was constructed (see Figure 1). The model includes three main links—experimental design, teaching process, and evaluation feedback—with AI technology fully integrated into each link.

In the experimental design phase, teachers use AI tools such as experimental design software to develop scientific and reasonable experimental plans according to teaching objectives and student characteristics. The software provides optimized suggestions for experimental steps, references for selecting equipment, and analyses of potential experimental errors based on big data. For example, when designing the "Propagation of Sound" experiment, the software recommended adding a comparative experiment on sound propagation effects in different media (solid, liquid, gas) based on past teaching data, making the experiment more scientific and comprehensive.

In the teaching process phase, intelligent teaching platforms provide students with diverse learning resources, including virtual experiments, instructional videos, and online guidance. Students can independently select learning content according to their progress and needs. For instance, during the "Growth Process of Plants" experiment, students can watch real-time monitoring videos of plant growth through the intelligent platform or enter a virtual experiment scene to simulate plant growth under different environmental conditions and observe morphological changes. Meanwhile, intelligent interactive devices such as smart bracelets are used to record students' experimental operation data in real time, such as operation time and accuracy of steps, providing a basis for subsequent evaluation.

In the evaluation feedback phase, intelligent evaluation systems are used to comprehensively assess students' experimental processes and results. The system not only analyses students' experimental reports to evaluate their scientificity, logic, and standardization but also assesses students' mastery of experimental skills—such as whether equipment is used correctly and steps are followed—based on operation data. According to evaluation results, the system automatically provides personalized learning suggestions and improvement plans to help students enhance their experimental abilities. Teachers can also adjust teaching strategies and optimize content based on evaluation data.

4.2. Specific Applications of AI Technology in Each Link of Experimental Teaching

4.2.1. Experimental Design Stage

Intelligent Experimental Scheme Generation: Teachers use intelligent experimental design platforms to input information such as experiment themes, teaching objectives, and student grades. The platform uses AI algorithms to screen and generate suitable experimental schemes from a massive database of cases. The scheme includes detailed experimental steps, required equipment, precautions, and explanations of possible phenomena. For example, when designing a "Circuit Connection" experiment, the platform-generated scheme not only included conventional series and parallel circuit connection methods but also provided extended experiments, such as using resistors with different resistance values to change current in the circuit and observe changes in bulb brightness, enriching experimental content.

Experimental Risk Assessment and Safety Guidance: For potentially dangerous experiments like "Combustion of Substances," AI systems assess risks during the experiment and provide detailed safety guidance for teachers and students. By simulating experimental processes, the system analyses potential hazards such as fires or explosions and proposes preventive measures and emergency procedures. Virtual reality technology is also used to allow students to practice safety drills in virtual environments, enhancing their safety awareness and emergency response capabilities.

4.2.2. Experimental Teaching Process

Combination of Virtual and Real Experiments: Virtual reality (VR) and augmented reality (AR) technologies are used to provide students with virtual experimental environments. In the "Revolution and Rotation of the Earth" experiment, students can wear VR devices to experience the Earth's movement in space and observe phenomena of day-night alternation and seasonal changes. Virtual experiments help students better understand abstract scientific concepts while reducing experimental costs and risks. Following virtual experiments, real experimental operations—such as simulating Earth's revolution and rotation using a globe and flashlight—allow students to apply knowledge from virtual experiments to practical operations, deepening their understanding and mastery.

Intelligent Learning Path Recommendation: Intelligent teaching platforms analyze students' real-time learning data to recommend personalized learning paths for each student. For example, during the "Buoyancy of Objects" experiment, the platform recommends experimental tasks and resources at different difficulty levels based on students' understanding of experimental principles, operational proficiency, and learning records. Students with weaker foundations are recommended simple buoyancy experiments and basic knowledge explanation videos, while those with stronger abilities are assigned complex buoyancy condition exploration experiments and extended reading materials and scientific research cases to meet diverse learning needs.

Real-Time Interaction and Guidance: During experimental teaching, students can ask questions to teachers through intelligent terminal devices, who use intelligent teaching assistants to provide real-time answers. The assistant can also automatically push relevant knowledge points and cases based on students' questions to aid understanding. For instance, when students do not understand the law of refraction angle changes in different media during the "Refraction of Light" experiment, the teacher uses the intelligent assistant to push animation demonstration videos and relevant experimental cases, helping students quickly grasp the concept.

4.2.3. Experimental Evaluation and Feedback

Multi-Dimensional Intelligent Evaluation: Intelligent evaluation systems assess students from multiple dimensions, including experimental operations, reports, and teamwork. In experimental operations, sensor and camera data are used to analyze indicators such as students' standard use of equipment, correctness of steps, and operation speed/accuracy; in report evaluation, natural language processing technology analyses the scientificity, logic, and language expression of students' submitted reports; in teamwork evaluation, interaction data such as communication frequency and contribution in group experiments are analysed to assess collaborative abilities. For example, in the "Conditions for Seed Germination" experiment, the intelligent evaluation system assesses students based on their performance in selecting seeds, preparing soil, controlling moisture and temperature, as well as the description of experimental processes, analysis of results, and conclusions in their reports.

Personalized Feedback and Suggestions: Based on evaluation results, the intelligent system generates personalized feedback reports for each student, pointing out strengths and weaknesses and providing specific improvement suggestions. For example, for students who operate slowly but accurately in "Circuit Connection" experiments, the report recommends after-class practice to improve speed; for those with unclear language in reports, the system recommends relevant writing guidance resources to enhance skills. Students can target their learning and improvements based on feedback reports.

5. Research Results and Analysis

5.1. Changes in Students' Interest in Science Experiments

Analysis of questionnaire data before and after the experiment showed a significant increase in students' interest in science experiments in the experimental class. Before the experiment, 40% of students in the experimental class expressed great interest in science experiments, compared to 38% in the control class; after the experiment, this proportion rose to 65% in the experimental class, versus 45% in the control class (see Figure 2).

Further analysis of interest changes in different experiment types revealed particularly notable growth in the experimental class's interest in virtual experiments and innovative experiments. Before the experiment, 30% of experimental class students were interested in virtual experiments, increasing to 55% afterward; interest in innovative experiments rose from 25% to 48%. This indicates that diverse experimental forms brought by AI technology, such as virtual experiments and intelligent programming-based innovative experiments, effectively stimulated students' interest in science experiments.

5.2. Improvement in Students' Experimental Operation Skills

Comparative analysis of experimental operation assessment scores between the two classes showed significant improvement in the experimental class's operational abilities. Assessment items included the use of experimental equipment, execution of steps, and recording/processing of data. Before the experiment, average scores were 70 in the experimental class and 68 in the control class, with no significant difference; after the experiment, the experimental class's average score rose to 85, compared to 75 in the control class (see Figure 3).

Analysis of specific experimental projects, such as the "Circuit Connection" experiment, showed that experimental class students were significantly superior in speed and accuracy of correct circuit connections. Experimental class students completed series and parallel circuit connections correctly in an average of 5 minutes with an error rate below 10%, while control class students took an average of 8 minutes with a 25% error rate. This indicates that AI-assisted teaching—through virtual experiment previews and real-time operation guidance—effectively improved students' experimental operation skills.

5.3. Development of Students' Scientific Inquiry Abilities

A scientific inquiry ability test was conducted on students in both classes, covering aspects such as asking questions, making hypotheses, designing experiments, collecting evidence, and analyzing arguments. Before the experiment, the average scores of the experimental class and the control class were 65 and 63 points respectively, with no significant difference. After the experiment, the average score of the experimental class increased to 82 points, while that of the control class was 70 points (see Figure 4). Specifically, in the "asking questions" dimension, the proportion of students in the experimental class who raised valuable scientific questions increased from 35% before the experiment to 60%, while the control class only increased from 32% to 38%. In the "experimental design" dimension, the proportion of students in the experimental class who could design reasonable experimental schemes increased from 40% to 70%, while the control class increased from 38% to 45%. This indicates that AI technology effectively promotes the development of students' scientific inquiry abilities by providing rich case references, intelligent prompts, and guidance.

5.4. Teachers' Feedback on AI-Assisted Teaching

Results of the teacher questionnaire survey show that 85% of teachers believe AI technology can significantly enrich teaching resources, and 78% of teachers indicate that the technology helps stimulate students' interest in learning. On the question of "whether they are willing to continue using AI to assist science experiment teaching," 90% of teachers answered "yes." However, teachers also reported some issues: 60% of teachers mentioned that AI devices occasionally experienced technical failures during teaching, affecting the teaching progress; 55% of teachers believed that current teacher training for AI-assisted teaching is insufficient, leading to difficulties in their teaching applications.

6. Research Conclusion

This study demonstrates through practice that the application of AI technology can effectively optimize primary school science experiment teaching. At the student level, it significantly enhances students' interest in science experiments and strengthens their experimental operation skills and scientific inquiry abilities. At the teacher level, it enriches teaching resources and methods, with most teachers expressing approval of AI-assisted teaching. However, there are still some problems in the application of AI technology in primary school science experiment teaching, such as the need to improve technical stability and further refine the teacher training system.

7. Research Limitations and Prospects

7.1. Research Limitations

First, the experimental sample of this study only selected two classes from one primary school, with a small sample size, which may limit the generalizability of the research results. Second, the experimental period was relatively short, and the long-term impact of AI technology on students' learning outcomes and the development of scientific literacy has not been deeply explored. Additionally, although every effort was made to control irrelevant variables during the research process, there may still be some unconsidered factors interfering with the experimental results.

7.2. Research Prospects

Future research can expand the experimental sample range by selecting schools and classes from different regions and at different levels to further verify the effectiveness and generalizability of AI technology in optimizing primary school science experiment teaching. Extending the experimental period to track students' long-term learning performance will help deeply analyze the sustained impact of AI technology on the formation and development of students' scientific literacy. Meanwhile, strengthening research on the deep integration of AI technology with primary school science experiment teaching, developing AI teaching tools and resources that better meet actual teaching needs, improving the teacher training system, and enhancing teachers' capabilities to apply AI technology in teaching will promote the high-quality development of primary school science experiment teaching.

References

[1] Kotsis K T. Integration of artificial intelligence in science teaching in primary education: Applications for teachers[J]. European Journal of Contemporary Education and E-Learning, 2024, 2(3): 27-43.

[2] Kotsis K T. Artificial Intelligence helps primary school teachers to plan and execute physics classroom experiments[J]. EIKI Journal of Effective Teaching Methods, 2024, 2(2).

[3] Huang X. Application of artificial intelligence APP in quality evaluation of primary school science education[J]. Educational Studies, 2024, 50(6): 1215-1235.

[4] Chang J, Liu D. Optimising learning outcomes: A comprehensive approach to virtual simulation experiment teaching in higher education[J]. International Journal of Human–Computer Interaction, 2025, 41(4): 2114-2134.

[5] Khoa B Q, Nguyen H T, Anh D B H, et al. Impact of Artificial Intelligence's part in supply chain planning and decision making optimization[J]. International Journal of Multidisciplinary Research and Growth Evaluation, 2024, 5(6): 837-856.