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AI-Enabled Teaching Reform and Practice of New Energy Courses: A Case Study of the "Hydrogen Powers the Future" Course

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Abstract: As an important part of the future energy system, hydrogen energy holds significant strategic significance in promoting energy structure transformation and achieving the "dual carbon" goals. University chemistry courses are the core carrier for cultivating scientific and technological talents in the hydrogen energy field, and their teaching content and methods are directly related to students' knowledge mastery and the development of innovative capabilities. However, current hydrogen energy teaching in universities still faces problems such as fragmented content, insufficient depth, and disconnection between theory and practice, making it difficult to meet the talent demand amid the rapid development of the hydrogen energy industry. This paper first analyzes the main existing problems of hydrogen energy teaching in university chemistry courses, then proposes optimization strategies from aspects such as constructing a systematic and complete hydrogen energy knowledge system, innovating teaching methods, and strengthening practical teaching links. Meanwhile, combined with the development trend of educational digitalization, it explores the empowering role of artificial intelligence (AI) in hydrogen energy teaching, including intelligent knowledge system construction, AI-driven teaching model innovation, and the expansion of industry-education integration practice systems, providing new ideas for improving the quality of university hydrogen energy education. The research argues that, on the premise of ensuring scientific and basic teaching, cutting-edge, interdisciplinary integration, and intelligent educational concepts should be integrated to comprehensively enhance students' theoretical literacy, engineering awareness, and scientific research innovation capabilities. The strategies proposed in this paper have certain reference value for promoting the construction of hydrogen energy talent training systems and supporting the high-quality development of the hydrogen energy industry.

Keywords: Hydrogen energy teaching; University chemistry education; Artificial intelligence; Teaching content reconstruction; Talent training

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1. Introduction

Against the background of in-depth adjustment of the global energy pattern and accelerated advancement of the "dual carbon" strategic goals, hydrogen energy, as a green, low-carbon, and widely applicable secondary energy source, is hailed as an important force driving the future energy revolution. China's issued "Medium and Long-

Term Plan for the Development of the Hydrogen Energy Industry (2021—2035)" clearly proposes to cultivate the hydrogen energy industry into a national strategic emerging industry and a future industrial direction. The rapid development of the hydrogen energy field has put forward new requirements for university chemistry education: it not only needs to consolidate students' theoretical foundation but also cultivate their innovative thinking, engineering capabilities, and interdisciplinary literacy, enabling them to be competent for the needs of future hydrogen energy technology R&D and industrial construction.

However, current hydrogen energy teaching in university chemistry courses still has problems such as fragmented content, insufficient depth, and weak practicality, making it difficult to meet the urgent demand for high-level talents amid industrial transformation and technological innovation. Therefore, systematically reconstructing the hydrogen energy teaching content system, innovating teaching methods, and strengthening industry-education integration practice have become important directions for university education reform [1–3].

At the same time, the rapid application of artificial intelligence technology in the field of teaching provides a new path for hydrogen energy teaching reform [4]. AI has significant advantages in educational resource integration, intelligent content push, virtual experiment simulation, and scientific research assistance, offering strong support for breaking traditional teaching limitations and improving teaching efficiency [5–7]. Deeply integrating AI into hydrogen energy teaching not only helps the digital transformation and cutting-edge expansion of the content system but also promotes students' active learning and the formation of scientific research capabilities, reserving more innovative talents for the development of the hydrogen energy industry [8].

Based on this, this paper analyzes the current situation and problems of hydrogen energy teaching in university chemistry courses, and proposes feasible optimization strategies from aspects such as knowledge system reconstruction, teaching method innovation, practical link strengthening, and AI technology empowerment. It is hoped to provide a reference for universities to build a high-quality hydrogen energy education system and contribute educational strength to China's energy transformation and development.

2. Current situation and problems of AI in university hydrogen energy education

2.1. Initial application of AI technology, but limited coverage

Currently, artificial intelligence technology has been initially applied in chemistry and energy education in some universities, such as using intelligent teaching platforms for personalized learning diagnosis and simulation software to assist virtual experiments of hydrogen energy reactions and equipment. However, overall, the popularity of AI in hydrogen energy teaching is still low, mostly remaining at the level of auxiliary display or simple data analysis, and has not formed a systematic intelligent teaching model. In addition, there are significant differences in resource construction among universities. Some institutions are unable to introduce mature AI educational tools due to technical, financial and other constraints, affecting the balanced advancement of AI teaching applications.

2.2. Imperfect teaching resources and data systems, unable to support in-depth, intelligent teaching

Hydrogen energy education has strong cutting-edge and interdisciplinary attributes, and its AI teaching content should cover multiple directions, such as hydrogen production, hydrogen storage, fuel cells, and electrocatalysis. However, the current AI teaching resources directly available for hydrogen energy education are still relatively scarce. For example, the construction of experimental data, material databases, and mechanism models is not complete, making it impossible to provide sufficient training samples for intelligent algorithms, such as machine learning. At the same time, some existing AI teaching systems lack a professional content update mechanism for the hydrogen energy field, resulting in teaching content being difficult to keep up with the rapid development of industrial technology, which restricts the improvement of students' scientific research and innovation capabilities by AI technology.

2.3. Lagging behind teachers' capabilities and teaching concepts, needing improvement in AI teaching integration

Despite the significant teaching advantages of AI-assisted teaching, university teachers' capabilities and awareness of applying AI in hydrogen energy education are generally insufficient. On the one hand, many chemistry teachers lack an AI technical background, are not proficient in the use of intelligent teaching tools, and find it difficult to effectively integrate them into classroom teaching and scientific research training; on the other hand, teaching concepts still focus on traditional knowledge transmission, and insufficient attention is paid to the cultivation of students' intelligent capabilities such as data analysis and simulation design. In addition, the AI teaching evaluation system has not been improved, leading to insufficient motivation for teachers to innovate teaching and slow promotion of intelligent teaching methods.

3. Conception of AI-enabled reconstruction of hydrogen energy teaching content

3.1. Construct an intelligent and systematic knowledge content framework

In the reconstruction of hydrogen energy teaching content, full play should be given to the advantages of artificial intelligence technology in knowledge integration, content correlation, and visual presentation. Through intelligent curriculum resource platforms, hydrogen energy knowledge should be reorganized and processed in depth to form a scientific and hierarchical intelligent knowledge system. Content setting can rely on knowledge graphs to network and display core knowledge such as the basic properties of hydrogen elements, hydride chemistry, hydrogen production technology, and hydrogen storage and application systems, guiding students to achieve cross-level cognition from macro energy strategies to molecular-level mechanism understanding. At the same time, AI technology can be used to dynamically update teaching resources, incorporating the latest scientific research progress, standard systems, and industrial cases into the curriculum content in real time, making hydrogen energy teaching no longer limited to textbook knowledge but developing in an open and intelligent direction, fundamentally improving the scientificity and completeness of teaching content.

3.2. Enhance the advanced nature and academic challenge of content

For the cultivation of high-level talents, the design of teaching content should emphasize the cognition of complex problems and the cultivation of scientific research capabilities. AI has powerful data analysis and model simulation capabilities, which can support the teaching process to break the traditional knowledge indoctrination model. For example, when explaining the electrocatalytic mechanism of fuel cells, introduce AI to assist in analyzing the relationship between electrocatalyst structure and activity, enabling students to use intelligent tools for calculation and prediction while understanding the theoretical basis, and put forward more innovative hypotheses and ideas in scientific research practice [9,10]. In addition, AI project-based learning tasks based on real data can be set, such as the optimization of hydrogen energy storage material performance and the construction of hydrogen production cost prediction models, transforming advanced knowledge into challenging learning practices, and promoting students' transformation from "knowledge receivers" to "problem solvers".

3.3. Strengthen the cutting-edge and research-oriented orientation of curriculum content

Hydrogen energy technology updates rapidly, so in content reconstruction, AI technology should be relied on to keep teaching content in sync with global scientific and technological progress. Teachers can use artificial intelligence to mine and analyze scientific research literature and patent databases, extract key breakthroughs and trends in the hydrogen energy field, and introduce content such as the development of new electrocatalytic materials, progress in large-scale solid-state hydrogen storage technology, and AI-assisted reaction path prediction into the classroom. At the same time, through AI simulation platforms, students can virtually build fuel cell devices and simulate electrocatalytic hydrogen production processes, experiencing the scientific research exploration process and enhancing their understanding and participation in real research [11,12]. Furthermore, the application of characterization methods such as mass spectrometry, gas chromatography, and XRD in hydrogen energy research can be displayed through intelligent experiment guidance systems, enabling students to clarify the logical basis and practical paths of hydrogen energy technology from the perspective of scientific research methods. Such settings not only enhance the inquiry and openness of the course but also lay an innovative foundation for students to carry out research in the hydrogen energy field in the future.

4. Optimization strategies for AI-enabled hydrogen energy teaching in universities

4.1. Build an intelligent and multi-dimensional hydrogen energy knowledge system

To meet the dual needs of educational digitalization and energy technology development, artificial intelligence should be fully used to optimize the construction of the hydrogen energy knowledge system. First, use knowledge graphs to realize the intelligent association of hydrogen energy-related concepts, mechanisms, and applications, enabling students to clearly understand the logical relationship between basic theories, technical routes, and industrial practices in hydrogen energy chemistry. Second, rely on AI content management platforms to dynamically update teaching resources, and automatically capture global hydrogen energy scientific research progress and technical patents through algorithms, keeping course content in sync with industry development. Third, promote inter-disciplinary data interconnection, such as introducing material science databases, electrocatalytic performance databases, and fuel cell simulation platforms, to achieve in-depth integration of interdisciplinary knowledge. Through intelligent resource integration, students can form a more comprehensive and systematic understanding of hydrogen energy, promoting the efficient construction of knowledge.

4.2. Innovate teaching methods to improve classroom participation and learning experience

Innovation of teaching methods based on the advantages of AI technology is an important way to improve classroom efficiency. First, use intelligent learning analysis technology to provide students with personalized learning paths and ability profiles, enabling teachers to teach students in accordance with their aptitude and optimize teaching strategies. Second, develop AI-driven virtual simulation experiments, such as the simulation of electrocatalytic hydrogen production interface processes and the virtual regulation of high-pressure hydrogen storage systems, allowing students to observe micro-reaction mechanisms in a safe environment and enhance learning experience [13,14]. In addition, use AI to assist in designing project-based learning content, such as using machine learning to predict catalyst activity and optimize the energy output of fuel cell stacks, enabling students to carry out inquiry-based learning around complex engineering problems. By introducing intelligent interaction and visualization technologies, classroom participation and learning effectiveness can be significantly improved, promoting the cultivation of students' active learning and critical thinking abilities.

4.3. Construct an industry-education integration intelligent practice system to enhance students' technical application capabilities

AI technology plays an important role in practical teaching. On the one hand, intelligent monitoring and data collection systems can be integrated into hydrogen energy experiments, such as real-time tracking of hydrogen production rate and intelligent analysis of electrochemical tests, making experimental results more accurate and reliable, and helping students understand the scientific significance of data. On the other hand, relying on AI industrial simulation platforms, jointly build virtual production lines and project training courses with hydrogen energy enterprises, allowing students to experience the entire process of hydrogen energy equipment manufacturing, operation, and maintenance. At the same time, promote the joint construction of scientific research and innovation bases by universities and enterprises, encouraging students to participate in AI-assisted research on key hydrogen energy technologies, such as computational simulation of solid-state hydrogen storage and development of fuel cell fault diagnosis models [15]. Under the guidance of teachers and the collaborative participation of enterprise engineers, students can accumulate real scientific research and engineering experience, improve professional competence, and lay a solid foundation for future integration into the hydrogen energy industry.

5. Conclusion

In summary, the application of artificial intelligence technology in university hydrogen energy teaching not only brings innovation to the presentation of knowledge but also provides important support for the cultivation of students' innovative capabilities, engineering practice capabilities, and interdisciplinary collaboration capabilities. Against the background of educational digital transformation and the rapid development of the hydrogen energy industry, universities should actively embrace AI technology, and through measures such as optimizing the teaching content system, innovating teaching methods, and strengthening practical teaching links, deeply integrate AI into the entire process of hydrogen energy talent training, promoting hydrogen energy education towards intelligence, precision, and high-quality development. It is believed that with the continuous maturity of AI technology and the deepening of hydrogen energy industry education, more high-level talents will be transported for the development of national strategic emerging industries, and universities will contribute to the realization of green, low-carbon, and energy transformation.

Disclosure statement

The author declares no conflict of interest.

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