Journal of Contemporary Educational Research, 2025, Volume 9, Issue 8
http://ojs.bbwpublisher.com/index.php/JCER
ISSN Online: 2208-8474
ISSN Print: 2208-8466

Exploration on the Optimization of Hydrogen Energy Teaching Content in College Chemistry Courses

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Abstract: With the rising global demand for energy and growing awareness of environmental sustainability, hydrogen energy has emerged as a promising clean and efficient alternative. Supported by national policies, both basic and applied research in hydrogen and hydrogen energy have seen significant advancements in recent years. Reflecting these developments, the teaching of "hydrogen element and hydrogen energy" in college level inorganic chemistry has gradually expanded. In the context of the new era, there is an urgent need to reform and enrich this teaching content to cultivate students' comprehensive abilities and align with the country's evolving demand for talent in the energy sector. This paper analyzes current challenges in the teaching of hydrogen energy within college chemistry curricula and proposes targeted strategies to optimize instructional content. The goal is to offer practical insights and references for educators seeking to improve the effectiveness and relevance of hydrogen energy education.

Keywords: Chemistry courses; Hydrogen energy teaching; Optimization of teaching content

Online publication: 17th September 2025

1. Introduction

The teaching of elemental chemistry has always been one of the key contents in inorganic chemistry teaching. Hydrogen, as the first element in the periodic table, has multiple isotopes; its elementary substance has various allotropes and there are many types of compounds formed by hydrogen.

In recent decades, significant progress has been made in research on hydrogen energy preparation, conversion, and its applications in industries, transportation, and other fields, which has enriched the teaching content of hydrogen elements and hydrogen energy in college chemistry. However, hydrogen energy teaching in college chemistry courses still has problems such as outdated content, lack of depth, and weak connection with practice, which need to be improved and optimized. Therefore, this paper explores the optimization of hydrogen energy teaching content in chemistry courses, hoping to ensure the scientific approach, cutting-edge nature, and advanced nature of the teaching content.

2. Current situation and problems of hydrogen energy teaching in college chemistry courses

2.1. Scattered teaching content, lack of systematic approaches

In the existing college chemistry curriculum system, knowledge related to hydrogen energy is often scattered across multiple courses such as inorganic chemistry, physical chemistry, and organic chemistry, lacking systematic approaches and coherence [1]. For example, inorganic chemistry covers basic knowledge such as the preparation and properties of hydrogen, while physical chemistry focuses on the study of thermodynamics and kinetics principles of hydrogen fuel cells, and organic chemistry mentions the application of hydrogen energy in organic synthesis. However, this content is relatively scattered, making it difficult for students to form a comprehensive and systematic understanding of hydrogen energy.

2.2. Insufficient teaching depth, failure to meet professional needs

In some college chemistry courses, the teaching content of hydrogen energy remains at the level of basic knowledge, with little coverage of cutting-edge technologies and research hotspots in the hydrogen energy field. With the rapid development of hydrogen energy technologies, such as new hydrogen production technologies, high-efficiency hydrogen storage materials, and advanced fuel cell systems, they have not been timely incorporated into the teaching content, leading to a disconnect between the knowledge students learn and practical applications [2]. In addition, the development and utilization of hydrogen energy are related to fields such as energy science, chemistry, physics, and materials science. However, the teaching of hydrogen energy-related content in college chemistry courses is often limited to the chemistry discipline itself, lacking cross-integration with other disciplines.

2.3. Disconnect between theory and practice, weak practical teaching links

Chemistry itself is a highly practical discipline, and practical teaching is extremely important for students to understand hydrogen energy-related content and master hydrogen energy technologies. In reality, during the teaching process of hydrogen energy, most teachers still adopt traditional lecture-based teaching methods, focusing on knowledge infusion while neglecting the cultivation of students' subject status and active learning ability [3]. Moreover, the experimental teaching link in hydrogen energy teaching is relatively weak. On the one hand, due to reasons such as expensive experimental equipment and complex experimental conditions, many colleges lack complete hydrogen energy experimental teaching facilities, making it difficult for students to personally experience and operate hydrogen energy-related experiments. On the other hand, the content of practical teaching is disconnected from actual production applications, lacking comprehensive and design-oriented experiments, which makes it difficult to cultivate students' innovative thinking and practical abilities.

3. Ideas for restructuring hydrogen energy teaching content

3.1. Enhancing the scientific and integrity of basic knowledge

To optimize the teaching content of hydrogen energy in university chemistry courses, a comprehensive review and integration should be conducted to build a complete hydrogen energy knowledge system. The teaching content can be divided into five modules following the principle of progressing from simplicity to complexity and from theory to practice, where the first module is an introduction to the hydrogen element, exploring its special position in the periodic table, tracing its origin, discovery process, and naming reasons, analyzing the existence forms and distribution laws of hydrogen in nature, and elaborating on the types of hydrogen isotopes, their separation and preparation methods, and isotope effects. The second module focuses on elemental hydrogen, explaining the concepts of orthohydrogen and parahydrogen, analyzing the differences in their physical properties and the mechanism of mutual transformation, systematically introducing the physical and chemical properties of hydrogen, and extending to discuss the allotropes of hydrogen. The third module emphasizes hydrides, comprehensively introducing their types, property characteristics, and preparation processes. The fourth module centers on coordination hydrides, analyzing their categories, preparation methods, and property performances. The fifth module focuses on hydrogen energy chemistry. Given the global challenges of energy shortage and environmental pollution, hydrogen energy, as an emerging energy source, has attracted much attention. This module highlights the application and development prospects of hydrogen energy in the energy field, including detailed explanations of the principles, advantages, disadvantages, and application prospects of various hydrogen production methods such as water electrolysis, fossil fuel reforming, biological hydrogen production, and photocatalytic hydrogen production. It also covers the characteristics and technical difficulties of different hydrogen storage methods like high-pressure hydrogen storage, liquid hydrogen storage, and solid-state hydrogen storage, helping students gain a comprehensive understanding of all aspects of hydrogen energy. Through such systematic restructuring, not only the logic and structure of the teaching material content are highlighted, but also the integrity and scientific of the basic knowledge are ensured. This enables students to master hydrogen energy knowledge comprehensively from basics to cutting-edge, and from theory to practice, laying a solid foundation for future research and work in related fields.

3.2. Highlighting the advanced and challenging nature of teaching content

The core goal of higher education is to cultivate comprehensive and innovative talents, which requires teaching content not only to consolidate basic knowledge but also to incorporate elements with advanced and challenging characteristics. In the process of restructuring hydrogen energy teaching content, teachers should expand the depth and breadth of the teaching content according to students' learning situation and the key and difficult points of the teaching content, and build a new knowledge framework [5]. At the same time, combine the cutting-edge research results and interdisciplinary innovative discoveries in the field of hydrogen energy to establish the depth of the teaching content [6]. For example, the introduction of elemental hydrogen can be expanded in the teaching content. For instance, orthohydrogen and parahydrogen are two types of hydrogen generated due to the different nuclear spin states of hydrogen atoms at symmetric positions in the molecule. The addition and deepening of this content are related to the study of atomic structure theory.

3.3. Reflecting the cutting-edge and research-oriented nature of the content

The teaching content of hydrogen energy should allow students to experience the cutting-edge and research-oriented nature of knowledge, so as to realize the cultivation of innovative talents. In hydrogen energy teaching, it is necessary to integrate scientific research achievements, innovative theories, and practical results in the field of hydrogen elements into teaching [7]. Teachers can present the latest progress in hydrogen energy chemistry, new hydrogen production technologies, important research findings, and introduce the industrial, agricultural, and medical applications of hydrogen.

Specifically, teachers can showcase the latest advancements in hydrogen energy chemistry and innovative breakthroughs in hydrogen production technologies. For example, the green hydrogen production methods developed by humans currently include photocatalytic hydrogen production, water electrolysis for hydrogen production, nuclear energy-based hydrogen production and more, which have great application potential in the future [8]. Teachers can also provide students with content related to characterization instruments used in scientific research as interest reading materials. For example, introducing the application of mass spectrometers, gas chromatographs, X-ray diffractometers, and other instruments in hydrogen energy research, helping students understand how to verify and optimize hydrogen energy technologies through scientific instruments. These extended contents can not only expand students' knowledge but also cultivate their scientific literacy and experimental skills, laying a solid foundation for future research and work in related fields.

4. Optimization strategies for hydrogen energy teaching content in college chemistry courses

4.1. Constructing a systematic and comprehensive knowledge system of hydrogen energy

To respond to the educational challenges of the new era and enhance students' comprehensive literacy, a sound knowledge system of hydrogen energy should be established. First, integrate scattered knowledge points related to hydrogen energy in chemistry courses. Knowledge of hydrogen energy is scattered across different chapters of various chemistry courses, requiring systematic integration [9]. For example, systematically integrate content such as hydrogen production methods (e.g., water electrolysis, fossil fuel reforming, biological hydrogen production, photocatalytic hydrogen production), the physical and chemical properties of hydrogen, hydrogen storage technologies (e.g., high-pressure hydrogen storage, liquid hydrogen storage, solid-state hydrogen storage), and application fields of hydrogen energy (e.g., fuel cells, distributed power generation, transportation) to form a complete hydrogen energy knowledge module. In the teaching process, content should be presented in an order from basics to applications and from theory to practice, guiding students to master hydrogen energy knowledge step by step and helping them build a comprehensive knowledge framework [10]. Second, supplement cutting-edge knowledge and update existing teaching content in a timely manner.

In recent years, with the development of materials science, significant breakthroughs have been made in the research of new hydrogen storage materials such as metal-organic frameworks (MOFs) and covalent organic frameworks (COFs). These materials exhibit excellent hydrogen storage performance due to their high specific surface area, adjustable pore structure, and superior chemical stability. In teaching, it is necessary to incorporate the structural characteristics, hydrogen storage mechanisms, and research status of these new hydrogen storage materials to broaden students' knowledge and horizons. At the same time, guide students to think about and discuss cutting-edge issues to stimulate their innovative thinking. Third, integrate interdisciplinary knowledge to achieve cross-disciplinary integration. Strengthen the integration of chemistry with other disciplines in hydrogen energy teaching [11]. For example, in the teaching of hydrogen storage and transportation, knowledge of thermodynamics and fluid mechanics from physics can be introduced to help students understand issues such as pressure and temperature changes, and flow characteristics during hydrogen storage and transportation. In the application field of hydrogen energy, such as hydrogen fuel cell technology, knowledge of electrochemistry and materials science can be combined to explain the working principle of the battery, the design of electrode materials, and the optimization of battery performance. Through the integration of interdisciplinary knowledge, students can understand and solve hydrogen energy-related problems from multiple perspectives, and their comprehensive literacy and innovative ability can be cultivated.

4.2. Innovating teaching methods to improve teaching effectiveness

The problem-oriented approach drives students to take the initiative in learning and thinking through practical problems. In hydrogen energy teaching, teachers can design problem chains, such as "How to improve the efficiency and stability of hydrogen fuel cells?" and "How to reduce the production cost of hydrogen to make it more market competitive?" Students can then independently consult materials, analyze, and research around these problems, gaining an in-depth understanding of hydrogen energy-related knowledge through solving practical problems. Meanwhile, teachers can carry out project-based learning activities, allowing students to complete tasks in groups [12]. Taking the design of a small hydrogen power generation system as an example, during the project implementation, students will apply knowledge from engineering, physics, and other fields to design schemes and conduct data analysis. This enables students to apply their knowledge in practice and enhances their ability to apply knowledge in the field of hydrogen energy.

In addition, it is necessary to strengthen the experimental teaching link of hydrogen energy and innovate experimental teaching methods. On the one hand, increase the proportion of comprehensive and design-oriented experiments. For example, design an experiment titled "Comparison and Optimization of Different Hydrogen Production Methods," allowing students to independently select experimental methods, design experimental schemes, conduct experimental operations, and analyze data. Through the experiment, students can compare the advantages and disadvantages of different hydrogen production methods and try to optimize the experimental process [13]. On the other hand, use virtual simulation experiment technology to carry out experiments with certain safety risks or that are difficult to implement in laboratories, such as high-pressure hydrogen storage experiments and large-scale hydrogen fuel cell experiments. This allows students to perform experimental operations in a virtual environment, observe experimental phenomena, and deepen their understanding of experimental principles.

4.3. Strengthen practical teaching links and enhance students' practical ability

Against the background of the Medium- and Long-Term Plan for the Development of the Hydrogen Energy Industry (2021–2035) and the Work Plan for Strengthening the Construction of Higher Education Talent Training System for Carbon Peak and Carbon Neutrality, it is emphasized that efforts should be made to accelerate the training of talents in the hydrogen energy field and the construction of related disciplines. Therefore, colleges and universities can strengthen cooperation with hydrogen energy-related enterprises, organize students to go deep into the front line of enterprise production, so that students can improve their cognition and understanding of hydrogen energy technologies through enterprise products, production equipment and process routes [14]. At the same time, enterprises can provide more high-quality internship opportunities for students, enabling them to practice and grow in the field of hydrogen energy. In addition, enterprise technicians can be invited to the school to carry out exchange activities, introduce the latest technologies and development trends in the hydrogen energy field, and inspire more talents to devote themselves to the hydrogen energy industry. Furthermore, students are encouraged to participate in teachers' research projects or independently carry out hydrogen energy-related scientific research activities. By participating in research projects, students can access cutting-edge research topics and methods, and develop their interest in scientific research and innovative abilities [15]. Teachers can provide students with some research topics or directions according to their actual situation, and guide them in literature review, experimental design, data analysis and other work.

5. Conclusion

To sum up, teaching content should not only reflect the imparting of knowledge, but also embody the cultivation of students' comprehensive abilities, and gradually guide students to build their own knowledge system and ability system. In view of the current problems in hydrogen energy teaching, the construction of the teaching content system should highlight scientifically, integrity and cutting-edge nature, supplemented by new teaching methods and practical links, so as to effectively improve the quality of hydrogen energy teaching and deliver outstanding talents for the development of the hydrogen energy industry.

Disclosure statement

The author declares no conflict of interest.

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