Research on the Strategies of Integrating Green Chemistry Concepts into High School Chemistry Teaching

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Abstract. Green chemistry is the core concept of modern chemical discipline development and a key carrier for cultivating the "scientific attitude and social responsibility" core literacy in high school chemistry. As a basic discipline closely related to life, the environment, and production, chemistry teaching not only needs to impart knowledge but also has the responsibility to cultivate students' environmental awareness and sustainable development concepts. This paper, based on the content of high school chemistry textbooks and classroom teaching practice, analyzes the necessity of integrating green chemistry concepts into high school chemistry teaching and explores it from four dimensions: theoretical teaching, experimental teaching, extracurricular practice, and evaluation system. The aim is to provide referenceable ideas for green chemistry teaching in high schools, promote the transformation of high school chemistry teaching from a knowledge-based approach to a literacy-based one, and achieve the coordinated development of chemistry teaching and ecological literacy cultivation.

Keywords: Green Chemistry; High School Chemistry; Core Literacy; Experimental Teaching

1 Introduction

The development of the chemical discipline, while promoting human social progress and improving production and life, has also brought about a series of ecological problems such as environmental pollution and resource waste. Green chemistry emerged as a response to these issues, with its core being to eliminate chemical pollution from the source and achieve environmental friendliness and efficient resource utilization in chemical processes. This concept is highly consistent with the current social advocacy of ecological civilization construction[1]. The high school stage is a critical period for the formation of students' values and core literacy. Integrating green chemistry concepts into high school chemistry teaching is not

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merely about popularizing environmental protection knowledge but involves embedding green chemistry ideas throughout the teaching process, establishing the correct understanding that "chemistry serves life and protects the environment," and discarding the one-sided view that "chemistry equals pollution."

From the current situation of high school chemistry teaching, some teachers are still bound by traditional exam-oriented thinking, with teaching focuses on college entrance examination points and problem-solving skills, neglecting the cultivation of subject literacy. Green chemistry concepts are often superficially touched upon in teaching and have not been truly integrated into classroom and experimental teaching. Meanwhile, traditional chemistry experiment teaching has problems such as large reagent usage, improper waste disposal, and obvious experimental pollution, which not only fail to meet the requirements of green chemistry but also are not conducive to the cultivation of students' environmental awareness. Based on this, this paper, grounded in high school chemistry teaching practice, deeply studies the systematic integration path of green chemistry concepts, and verifies the practical effects through specific teaching cases. This not only enriches the theory of high school chemistry teaching but also provides practical references for front-line teaching, contributing to the high-quality development of high school chemistry teaching [2].

2 Core Connotations and Necessity of Integrating Green Chemistry Concepts into High School Chemistry Teaching

Green chemistry, also known as environmental-friendly chemistry, has its core principles summarized as the "5R principles," namely, reduction, reuse, recycling, regeneration, and rejection of harmful substances. Its essence is to use chemical principles to reduce or eliminate the use and generation of harmful substances in chemical experiments and industrial production, pursue the maximization of atomic utilization, and achieve the harmonious coexistence of chemistry and the ecological environment[3].

Compared with traditional chemistry that focuses on "how to treat pollution," green chemistry emphasizes "preventing pollution from the source." This concept runs through various knowledge points in high school chemistry, such as the properties of substances, chemical reac-

tions, experimental operations, and chemical production, making it an indispensable part of high school chemistry teaching.

The "General Senior High School Chemistry Curriculum Standards (2017 Edition, Revised in 2020)" (hereinafter referred to as the "New Curriculum Standards") is based on the essence of the chemistry discipline and the demands of the times, and has established a five-core chemistry literacy system, namely "Macroscopic Identification and Microscopic Analysis", "Change Concepts and Equilibrium Thinking", "Evidence Reasoning and Model Cognition", "Scientific Inquiry and Innovation Awareness", and "Scientific Attitude and Social Responsibility". It takes the cultivation of literacy as the core orientation of senior high school chemistry teaching, completely breaking the traditional knowledge-based teaching model of exam-oriented education[4]. Among them, the "Scientific Attitude and Social Responsibility" literacy clearly puts forward specific educational requirements: students should deeply understand the important contributions of chemistry to social development and human life, while paying attention to the environmental problems and safety hazards that may be brought about by chemical processes; establish the concept of green, low-carbon and sustainable development, and have the responsibility awareness of respecting nature and protecting the ecology; be able to use the chemical knowledge they have learned to analyze and solve environmental problems in actual production and life, actively participate in environmental protection activities, and form a scientific chemical value view and sense of social responsibility.

In the setting of course content, the New Curriculum Standards also incorporate the requirements of green chemistry multiple times. It explicitly lists "Chemistry and Sustainable Development" as an important module in the compulsory course, covering the rational use of chemicals, environmental protection and green chemistry, comprehensive utilization of resources, etc. In the elective compulsory courses, for modules such as organic chemistry foundation and chemical reaction principles, it puts forward specific teaching requirements such as "paying attention to the atomic economy of organic synthesis and understanding green synthetic processes" and "understanding the application of chemical reaction rates and chemical regulation in chemi-cal production and establishing the concept of green production".

3 Existing Problems in the Integration of Green Chemistry Concepts in High School Chemistry Teaching

1. Most high school chemistry teachers can understand the concept of green chemistry, but in actual teaching, due to the low proportion of green chemistry-related examination points in the college entrance examination, they often treat it as an extended topic, merely mentioning it briefly in the corresponding textbook chapters without delving into the green chemistry connotations behind the knowledge points or designing specific teaching segments. This results in superficial integration of the concept, making it difficult for students to form a systematic understanding of green chemistry.

2. The current high school chemistry experiment teaching is limited, and there are many shortcomings. Firstly, the experimental equipment is traditional, with large-capacity conventional instruments often used, leading to excessive reagent consumption and a large amount of pollutant generation. Secondly, the experimental procedures are rigid, with teachers only requiring students to follow the steps without guiding them to consider environmentally friendly optimization plans. Thirdly, the disposal of experimental waste is casual, lacking awareness and measures for classification and recycling, with the direct emission of waste gas and random dumping of waste liquid being common.

3. High school chemistry textbooks contain a wealth of implicit green chemistry materials, such as the atomic utilization rate of chemical reactions, the development of new energy, green processes in chemical production, and pollution control. However, some teachers lack the awareness of integrating these materials, merely explaining the surface knowledge of the textbooks without deeply combining green chemistry concepts with the knowledge points, resulting in a disconnection between knowledge and concepts, making it difficult for students to associate green chemistry ideas with the chemical content they have learned.

4 Paths and Practices for Integrating Green Chemistry Concepts in High School Chemistry Teaching

Combining the characteristics of high school chemistry teaching and students' cognitive patterns, and focusing on the four core links of classroom

teaching, experimental teaching, extracurricular practice, and teaching evaluation, a systematic path for integrating green chemistry concepts is constructed, along with original teaching cases to ensure the practicality and effectiveness of teaching practices.

1. Textbooks are the core basis for teaching. Teachers need to systematically sort out the green chemistry knowledge points in high school chemistry textbooks, integrate scattered materials into systematic teaching content, and incorporate them into daily theoretical teaching, allowing the green chemistry concept to run through the entire process of knowledge explanation.

In the teaching of elements and compounds, green chemistry ideas can be integrated by combining the properties of substances. For example, when teaching "Sulfur and Its Compounds," the pollution of sulfur dioxide and the formation of acid rain can be analyzed, guiding students to think about the tail gas treatment plans for sulfur dioxide in industrial production, and explaining the chemical principle of lime desulfurization to help students understand the "refuse, reduce" principle. In the teaching of chemical production-related content, green chemical processes can be integrated by combining industrial processes[5]. For example, when teaching the development and utilization of seawater resources, the green processes of seawater desalination and bromine extraction from seawater can be analyzed, emphasizing resource recycling and utilization; when teaching metal smelting, the environmental friendliness of different smelting methods can be compared, guiding students to consider the advantages of green smelting technologies, allowing students to experience the practical application of green chemistry in industrial production.

2. Experimental teaching is a core link for integrating green chemistry concepts. Through comprehensive green transformation of experimental equipment, reagent usage, operation procedures, and waste treatment, the environmental friendliness, safety, and efficiency of experimental teaching can be achieved.

Microscale experiments use miniaturized instruments, which can significantly reduce reagent consumption and pollutant generation, making the operation simpler, safer, and faster. For example, in the "Reaction of Copper with Nitric Acid" experiment, the conventional experiment uses large amounts of rea-

gents and generates a large amount of toxic nitrogen oxides. By using microscale experiments, with a spot plate and syringe as the reaction devices, a small amount of copper wire and nitric acid are used, and the tail gas is absorbed by cotton soaked in sodium hydroxide solution, achieving a closed reaction without the leakage of toxic gases.

For experiments that produce toxic or harmful gases, the equipment should be modified to be sealed and a tail gas absorption step should be added to prevent gas diffusion and air pollution. For instance, in the "Preparation and Properties Test of Chlorine" experiment, a tail gas absorption device is installed on the basis of the traditional setup, using sodium hydroxide solution to absorb the excess chlorine gas. Meanwhile, the properties test is integrated into a sealed device to reduce chlorine leakage, ensuring the safety of teachers and students and adhering to the principle of green chemistry that "harmful substances should not be allowed to spread".

The experimental phenomenon is clear, and students can complete the operation quickly, directly experiencing the advantages of green experiments. Establish a classification and treatment mechanism for experimental waste to guide students in the collection and treatment of waste liquids, waste solids, and waste gases. For example, acidic and alkaline waste liquids can be collected centrally and neutralized before being discharged after meeting standards; waste liquids containing silver, copper, and other metal ions can be treated through chemical precipitation and displacement reactions to recover metals. Solid reagents and broken glass left over from experiments can be classified and recycled, and reusable reagents can be purified and reused, allowing students to master the principle of "recycling and reuse" in practice.

3. Extracurricular practice is an extension of classroom teaching, enabling students to transform theoretical knowledge of green chemistry into practical actions and strengthen their environmental awareness. Teachers can design diverse green chemistry practical activities based on teaching content to replace traditional written homework and enhance students' exploration abilities. Organize green chemistry invention and creation activities, encouraging students to improve traditional experimental equipment and design green experimental plans, such as making miniature experimental instruments and developing simple exhaust gas absorption devices. Hold green chemistry science popularization and publicity activities, allowing students to

create hand-drawn posters and promotional posters to spread knowledge of green chemistry and environmental protection to classmates and family members, creating a green chemistry learning atmosphere.

5 Conclusion

Integrating green chemistry concepts into high school chemistry education is an inevitable trend of new curriculum reform and a vital approach to cultivating students' disciplinary core literacy and ecological cognition. Oriented by pollution mitigation and resource conservation, green chemistry advocates eco-friendly chemical practices, aligning well with the core objectives of modern competency-based chemistry education. It bridges academic knowledge and real-life environmental challenges, enabling students to understand the social value of chemistry learning.Instead of merely focusing on chemical principles and reaction formulas, modern chemistry education attaches great importance to practical ecological education to adapt to global sustainable development demands.

Nevertheless, current chemistry teaching has prominent deficiencies. Restricted by exam-oriented pedagogy, most teachers prioritize theoretical instruction and academic assessment while ignoring green concept infiltration. Conventional experiments adopt hazardous reagents with excessive dosage and substandard waste disposal.Such improper operation may bring potential safety hazards and secondary pollution in campus laboratories. In addition, latent green chemistry resources in textbooks are underutilized, decoupling classroom teaching from real environmental practices. Most teachers lack systematic green teaching designs and seldom combine chemical knowledge with daily environmental problems such as industrial waste gas and water pollution.

To address these issues, teachers should update traditional teaching concepts, explore textbook green chemistry resources, and optimize experimental designs via microscale and closed-loop experiments. Diversified extracurricular practices and multidimensional evaluation systems can effectively embed green chemistry notions throughout the whole teaching process. Teachers can also organize environmental investigation activities and chemistry innovation competitions to deepen students' practical experience. This systematic teaching practice cultivates students' professional literacy

and environmental accountability. It fosters high-quality comprehensive talents and provides pedagogical support for the sustainable development of chemistry disciplines and the progress of ecological civilization construction. Ultimately, it helps students establish lifelong eco-friendly awareness and positive social responsibility.It also enables teenagers to apply professional knowledge to solve practical environmental problems in daily life.

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