Education Reform and Development, 2025, Volume 7, Issue 3
https://ojs.bbwpublisher.com/index.php/ERD
Online ISSN: 2652-5372
Print ISSN: 2652-5364

The Integration of Green Chemistry Concepts into Inorganic Chemistry Education for Chemical Majors

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Abstract: Against the backdrop of green development, there are heightened demands for cultivating chemical professionals with specialized competencies. To meet these demands, integrating the concept of green chemistry into Inorganic Chemistry teaching is imperative. As Inorganic Chemistry serves as a foundational course for chemistry and chemical engineering majors, pedagogical reform plays a pivotal role in nurturing professionals versed in green chemistry. This integration not only enables students to internalize green chemistry principles—thereby strengthening their environmental consciousness and scientific literacy—but also revitalizes Inorganic Chemistry curricula while advancing the quality of chemical education as a whole. This study establishes a strategic framework for green chemistry integration in inorganic chemistry education through three pillars: curricular innovation, faculty development, and cross-disciplinary synergies.

Keywords: Green chemistry; Chemical major; Inorganic chemistry; Integration

Online publication: April 3, 2025

1. Introduction

The rapid growth of the global economy has been accompanied by severe environmental pollution caused by traditional chemical industries. Issues such as resource depletion and ecological degradation have emerged as critical challenges worldwide, necessitating urgent action. Under this background, chemical teachers in colleges and universities should assume the responsibility of teaching and educating people, and integrate the concept of green chemical industry into inorganic chemistry teaching, aiming at preventing natural pollution from the source and creating a circular social environment.

2. Connotation and characteristics of green chemistry

2.1. Connotation elaboration

Green chemistry (also termed environmentally benign chemistry, sustainable chemistry, or clean chemistry) is

an emerging discipline that uses chemical principles and methods to reduce or eliminate the use and production of reaction raw materials, catalysts, solvents, and reagents, products and by-products that are harmful to human health, community safety and ecological environment [1]. This means that in the chemical process, it is necessary to fully consider the selection of raw materials, the optimization of reaction conditions, the environmental protection of catalysts and solvents, and other factors to achieve the goal of green chemistry.

2.2. Characteristic analysis

(1) Environmental friendliness

Green chemistry emphasizes minimizing or eliminating the negative impact on the environment in the whole process of the design, manufacture, application and disposal of chemical products [2].

(2) Atomic economy

Green chemistry pursues a high utilization rate of chemical reaction, that is, all the atoms in the reactant should be converted into the target product as much as possible, reducing the generation of by-products and waste of resources.

(3) High energy efficiency

Green chemistry focuses on the energy efficiency of chemical reactions, that is, to meet the needs of chemical reactions while reducing energy consumption as much as possible [3].

(4) Sustainability

Green chemistry emphasizes the sustainability of chemical processes, that is, meeting current human needs without compromising the ability of future generations to meet their needs. This requires chemists to fully consider environmental factors when designing and optimizing chemical processes, adopt environmentally friendly technologies and methods, and promote the green development of the chemical industry [4].

3. The necessity of infiltrating the concept of the green chemical industry into the teaching of chemical majors in universities

In the teaching reform of chemical majors in colleges and universities, the infiltration of green chemical concepts plays a vital role in the development of students' comprehensive quality and the reform of professional teaching. Therefore, it is urgent and necessary to carry out green chemistry education, which can be shown as follows:

(1) It is necessary for the era to cultivate high-quality chemical talents with a green development vision [5]. With the awakening of global environmental awareness, green chemistry has become an important yardstick for measuring the comprehensive quality of chemical talents. The teaching of chemical engineering in colleges and universities should keep up with the pace of the era, integrate the concept of the green chemical industry into the curriculum system, and cultivate high-quality talents with solid professional knowledge and a strong sense of environmental protection to meet the urgent demand of the society for green chemical technology [6].

(2) The introduction of green chemical concepts is the key to enriching the teaching system of chemical majors. In the 21st century with the explosion of knowledge, a single professional knowledge has been challenging to meet the complex and changing needs of the industry. Green chemical industry, as the

product of the interdisciplinary integration of chemistry, environmental science, material science and other disciplines, the introduction of its teaching content helps broaden students' knowledge horizons, build a complex and comprehensive knowledge structure, and lay a solid foundation for coping with the challenges in the chemical industry in the future [7].

(3) Teaching of green chemical concept is an important way to popularize the concept of green development. Through classroom teaching, experiment, and practical training, the concept of green chemical industry is deeply planted in the minds of students, which can not only enhance students' awareness of environmental protection, but also stimulate their enthusiasm to explore green chemical technology and contribute to the promotion and application of green chemistry.

4. The problems in green chemistry education and teaching in colleges and universities

4.1. The educational concept needs to be updated urgently

From the perspective of teachers, most chemical teachers in colleges and universities have realized the important role of green chemistry education in student development and curriculum reform, and some teachers have gradually mastered the essential requirements and specific measures for cultivating students' green concept. However, some teachers still devote more time and energy to cultivating students' professional skills. Green chemistry education is only a supplement to and expansion of chemical teaching, thus it has not been fully integrated into the curriculum [8]. In addition, from the perspective of students, some students hold cognitive biases, perceiving green chemistry education as optional. Consequently, they prioritize exam preparation and technical skills over engaging with sustainability concepts. Other students just deal with the exam or even escape from learning, resulting in a lack of identity and participation in green chemistry education. In combination with the above content, there is a certain deviation between the teachers' educational concept and the students' cognitive concept, which makes green chemistry education ineffective.

4.2. The teaching mode still needs to be improved

According to the actual teaching situation, it can be seen that teachers pay more attention to teaching students theoretical knowledge, and do not create a suitable practical teaching environment for students, resulting in the lack of time and opportunities for practical operation, observation, and thinking, and even the classical or essential chemical experiments are ignored by students. In addition, teachers are accustomed to using the education model of explanation + recitation + homework + examination. In this process, students mostly memorize by rote, and it is difficult to effectively understand the connotations of concepts and definitions, they cannot flexibly use chemical formulas and master experimental steps, nor can they fully understand the connotation and value of the concept of green chemistry [9]. In this way, it is difficult to effectively train students' observation ability, innovation ability and thinking ability, and even limit their individual development, unable to improve their comprehensive quality.

4.3. The teaching staff needs to be enhanced

It is understood that some teachers who taught Inorganic Chemistry in Chinese colleges and universities have not integrated the concept of green chemistry into classroom teaching, and even if integrated, most of them are shallow and one-sided, and cannot give full play to the educational value of the concept [10]. Specifically

speaking, at this stage, some teachers use textbooks about the concept of green chemistry with less content, especially in some experimental design links that rarely show environmental protection awareness, and green chemistry concept, and do not rely on the network platform, or teaching software to integrate green education resources, making green education results are not good. In addition, most teachers do not have a thorough understanding of the concept of green chemistry, so they are not proficient in the penetration method and do not have a clear understanding of the learning basis of students. They only carry out simple device assembly and experiment teaching but do not penetrate the concept of green education into it.

5. The infiltration path of green chemistry concept in inorganic chemistry teaching of Chemical Engineering majors

5.1. Infiltrating the concept of green chemistry and updating the concept of education and teaching

In the inorganic chemistry teaching of chemical majors, infiltrating the concept of green chemistry is an important mission given to education by the era. As Inorganic Chemistry teachers, we should actively explore and practice a series of novel educational concepts to deepen green chemistry's teaching penetration.

(1) The emphasis is on student-oriented teaching

In the teaching process of green chemistry, teachers not only teach the basic theory and technology of green chemistry but also pay more attention to stimulating students' internal learning motivation, encouraging students to actively explore the connotation and value of green chemistry, and letting students understand the essence of green chemistry in practice through group discussion, case analysis, and other forms.

(2) Teaching students in line with their ability

Teachers should make individualized teaching plans according to different students' learning characteristics and needs [11]. In the teaching of green chemistry, teachers pay attention to guiding students to choose suitable green chemistry research directions according to their interests and specialties, such as the design of green catalysts, the development of green solvents, etc. Through project-based learning and scientific research practice, students can deepen their understanding and application of green chemistry concepts in practice.

(3) The concept of green chemistry should be implemented

Teachers should carry this concept through the whole process of inorganic chemistry teaching. In terms of teaching content, teachers should pay attention to introducing the latest research results and cutting-edge technologies of green chemistry, such as green synthesis methods and eco-friendly materials, to broaden students' knowledge horizons. In addition, in terms of teaching methods, teachers advocate the use of green chemistry teaching methods, such as virtual simulations, remote experiments, etc., to reduce the impact on the environment during the experiment process and cultivate students' environmental awareness and responsibility.

5.2. Infiltrate the concept of the green chemical industry and innovate inorganic chemistry teaching

Today, with the rapid development of science and technology, teaching methods and teaching models are undergoing unprecedented changes. There are more diversified teaching forms such as live broadcasting and

video broadcasting, and teaching resources such as micro-classes and MOOCs, which can innovate teaching methods and stimulate students' interest in learning. Under the concept of green chemical engineering, teachers should keep up with the pace of the era, change their teaching thinking, reconstruct teaching mode, and try to organically integrate traditional classrooms with information technology to activate the classroom atmosphere and improve teaching quality [12]. To be specific, teachers can leverage information technologies (e.g., 3D animations) to simplify complex concepts and enhance student engagement, promote teacher-student communication through questioning and interactive teaching methods, etc. However, it should be noted that teachers should infiltrate the concept of the green chemical industry at appropriate opportunities to deepen students' cognition and understanding of the concept [13]. For example, when explaining content related to "molecular structure," teachers can design practice activities of "green molecular architect," requiring students to play the role of environmental architects and build stable and environmentally friendly molecular structures by relying on virtual laboratory software. In this process, students must ensure molecular stability while minimizing harmful byproducts. In this way, students not only deepen their understanding of the molecular structure of inorganic chemistry but also stimulate their interest in green chemical technology. Teachers adopt the teaching method of edutainment, which can make students feel the charm of green chemistry in practice, and lay a solid foundation for cultivating green chemistry talents.

5.3. Permeate the concept of green chemistry and reform the teaching evaluation system

Teachers can innovate the Inorganic Chemistry course evaluation system by incorporating the concept of green chemistry. In this process, teachers should take into account the actual situation of students and conduct comprehensive evaluations on students from multiple dimensions to ensure the objectivity, fairness, and comprehensiveness of teaching evaluation results.

(1) Evaluate students' attention to green chemistry

In the process of learning inorganic chemistry, the more attention students pay to green chemistry, the more positive their learning attitude is. On the contrary, they should be evaluated negatively, regardless of their learning foundation and intelligence level.

(2) Evaluate the degree of students' consolidation of green chemistry knowledge

Students should regularly review and consolidate their knowledge of green chemistry, and use personalized language memorization to solidify it into their knowledge base for a long time.

(3) Evaluate students' ability to apply green chemistry knowledge

The purpose of learning is to imitate, copy and innovate, students should be able to learn the knowledge of predecessors, realize the complete copy of knowledge, and transform it into their skilled skills.

(4) Evaluate students' ability to apply green chemistry knowledge

Students should not only master the knowledge but also transform the knowledge into practical operation ability. After mastering the knowledge and skills of green chemistry, students should be able to apply them in experimental operations and even in daily life, experience the charm of green chemistry through practice, and try to solve problems in real-life [14].

5.4. Infiltrate the concept of green chemistry and carry out professional training for teachers

The professional quality, environmental awareness, and professional quality of chemical majors play a crucial

role in the teaching effectiveness of the whole course. In order to ensure the natural penetration of the concept of green chemistry in the classroom, colleges and universities should actively organize teachers to carry out professional training, aiming at improving their professional quality and green chemistry awareness [15].

(1) A diversified training system should be established

Colleges and universities should organize various training activities, including seminars, symposiums, advanced courses and other forms, aiming to comprehensively and deeply popularize the knowledge of green chemistry and strengthen teachers' understanding and recognition of green chemistry. Alternatively, colleges and universities can also invite experts and scholars in the field of green chemistry at home and abroad to hold lectures and exchanges, so that teachers can grasp the cutting-edge trends of green chemistry and broaden their academic horizons.

(2) Focus on young teachers

Young teachers are a fresh force in the cause of higher education, and they have a stronger ability to accept and implement new educational concepts. To this end, colleges and universities can formulate and implement special training programs, such as green chemistry teaching seminars and teaching design workshops, to help young teachers update their educational concepts and master the essence of green chemistry teaching design, to effectively integrate green chemical elements into inorganic chemistry teaching.

(3) Strengthen practice-oriented teaching

Colleges and universities encourage teachers to apply the concept of green chemistry to practical teaching, and constantly improve the effectiveness of green chemistry teaching by designing green chemistry experiments, developing green chemistry teaching cases, and cultivating students' green environmental awareness and innovation ability.

6. Conclusion

In summary, from the perspective of quality-oriented education reform, inorganic chemistry teachers of chemical engineering majors in colleges and universities should infiltrate the concept of green chemistry by combining the characteristics of curriculum teaching, the development needs of students, and the goal of green reform. Measures such as updating education and teaching concepts, innovating inorganic chemistry teaching, enriching inorganic chemistry teaching and reforming the teaching evaluation system can be adopted to achieve the teaching goal of infiltrating the concept. Finally, they can promote the green development of the chemical industry and promote the healthy development of society.

Funding

Undergraduate Teaching Research Project of Wuhan Textile University, "Exploration and Practice of Green Chemistry Concept in Inorganic Chemistry Teaching Leading by Digital Empowerment" (Project No.: 2024JYB012); Postgraduate Excellent Course Catalytic Chemistry (Project No.: 202301050); Graduate Education Reform Project, "Construction and Practice of Teaching Quality Evaluation System for Chemical and Chemical Graduate Students under the background of Education Digitization" (Project No.: 202301007); Wuhan Textile University National Demonstration Center for Experimental Textile Printing & Dyeing Education

Disclosure statement

The authors declare no conflict of interest.

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