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Exploration of Teaching Mode of Inorganic Synthetic Chemistry Course from the Perspective of Collaborative Education in Science, Education and Industry

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Abstract

With the rapid development of the social economy and the continuous progress of technology, there is an increasing demand for high-quality chemical professionals with solid professional knowledge, strong practical ability, and innovative thinking in various industries. As a fundamental course in the field of chemistry, Inorganic Synthetic Chemistry plays a crucial role in cultivating students' chemical synthesis skills, constructing a comprehensive chemical knowledge system, and laying the foundation for their future professional development. However, traditional teaching models have gradually exposed significant shortcomings in meeting the demands of modern talent cultivation. The collaborative education model integrating science, education, and industry provides new perspectives and effective solutions to solve these problems. By integrating the educational resources of universities, the innovative capabilities of research institutions, and the practical platforms of the industry, the establishment of a collaborative teaching model holds great promise for comprehensively enhancing the teaching quality of Inorganic Synthetic Chemistry and cultivating applied professionals who are well-adapted to the evolving needs of the era.

Keywords

Inorganic Synthetic Chemistry, Education, Science, Industry.

1. Introduction

Inorganic Synthetic Chemistry, as an important branch of the chemical sciences, plays a crucial role in numerous fields such as materials science, energy, and environmental science. The Inorganic Synthetic Chemistry course aims to cultivate students with the basic principles, methods, and skills for synthesizing inorganic compound, laying a foundation for subsequent professional learning and future careers in related industries. However, traditional teaching methods often focus on theoretical knowledge, resulting in a disconnect between course content and practical applications, weak practical teaching links, and insufficient cultivation of students' innovative abilities. This makes it difficult to meet the growing demand for high-quality chemical professionals who possess both innovative thinking and practical skills.

Taking Qilu University of Technology (Shandong Academy of Sciences) as an example, Inorganic Synthetic Chemistry is a core professional course for undergraduate chemistry students. This course employs methods such as intensive lectures, case studies, videos, and discussions to systematically describe the design of new materials and the synthesis of inorganic compounds, primarily from the perspectives of synthetic methods and the synthesis of typical materials. It aims to familiarize students with breakthrough advancements in the synthesis of various inorganic materials and their remarkable applications, thereby broadening their horizons and cultivating their learning and critical thinking abilities. Specific content includes the application

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of modern theories of material structure, fundamental principles of chemical reactions, and basic knowledge of elemental chemistry in the field of synthetic chemistry, as well as the synthesis methods and pathways of typical inorganic compounds and the cutting-edge technological developments in inorganic synthesis. Through this course, students can gain a comprehensive understanding of the design of inorganic synthesis routes, the selection of synthesis methods and conditions, the analysis and testing of synthesized product structures, and the characterization of product properties. Upon completing this course, students will be well-prepared for subsequent courses such as professional chemistry experiments, advanced disciplinary lectures, and graduation theses. It also fosters scientific literacy and rigorous research thinking, inspires a sense of contributing to the nation through science and technology, and lays a solid foundation for future careers in inorganic material synthesis, chemical separation, and identification within the field of chemistry.

The collaborative education model integrating science, education, and industry emphasizes the deep integration of education, scientific research, and industrial practices [1]. By organically combining the educational resources of universities, the innovative capabilities of research institutions, and the practical platforms of the industry, it provides a novel approach to addressing the limitations of traditional teaching models. Under this framework, the teaching of inorganic synthetic chemistry courses can be more closely aligned with actual production and cutting-edge scientific research, thereby enhancing students' comprehensive competencies and better preparing them for future career development. Therefore, exploring the teaching modes of such courses within this perspective holds significant practical importance.

2. Issues in Traditional Inorganic Synthetic Chemistry Course Teaching

2.1. Content of Teaching

2.1.1. Weak Integration of Theory and Practice

Traditional teaching materials primarily focus on theoretical knowledge, with limited introduction to specific application cases of Inorganic Synthetic Chemistry in industrial production and scientific research. For example, when explaining a particular synthesis method, the content often only covers the reaction principles and steps, while rarely mentioning the process conditions, quality control, and practical challenges faced when applying this method to produce important inorganic materials in real-world scenarios. This approach makes it difficult for students to connect theoretical knowledge with practical applications, resulting in a superficial understanding and an inability to apply knowledge to solve real-world problems.

2.1.2. Insufficient Incorporation of Cutting-Edge Knowledge

The field of inorganic synthetic chemistry is rapidly evolving, with new synthesis methods and materials continuously emerging. However, the updating of teaching materials lags behind, and the latest scientific achievements and frontier knowledge are often not integrated into the curriculum in a timely manner. As a result, students lack exposure to the latest developments in the field, which limits their horizons and the cultivation of innovative thinking. Upon entering the industry after graduation, they may find a significant gap between the knowledge they have acquired and the new technologies used in actual scientific research and production.

2.2. Teaching Methods

Classroom teaching is predominantly teacher-centered, with students passively receiving knowledge. While this approach ensures the systematic delivery of knowledge, it lacks effective interaction between teachers and students, as well as among students themselves. This makes it difficult to stimulate students' enthusiasm for active thinking and participation. For instance, when teachers explain complex reaction mechanisms, they often rely on textbook explanations without providing opportunities for students to ask questions or engage in in-depth discussions.

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Consequently, students may resort to rote memorization without truly grasping the essence of the knowledge.

2.3. Faculty Team

2.3.1. Relative Lack of Practical Experience

Among the faculty in higher education institutions, some teachers transition directly from academic institutions to teaching positions without gaining practical experience in industrial production or research institutions working on actual inorganic synthesis projects. As a result, they can only explain related knowledge from a theoretical perspective and are unable to vividly convey practical skills and experiences using real-world cases. This limits their ability to effectively guide students in developing practical skills.

2.3.2. Insufficient Connection with Industry

Taking Qilu University of Technology (Shandong Academy of Sciences) as an example, there are currently five teachers engaged in teaching Inorganic Synthetic Chemistry course, including two professors, one associate professor, and two lecturers. These faculty members are primarily focused on teaching and research, with limited opportunities for communication and collaboration with industry. As a result, they lack awareness of the latest technological demands and talent standards in the field. This leads to a misalignment between the teaching content, training direction, and the actual needs of the industry. Consequently, the students trained may not fully meet the requirements of enterprises for professionals in inorganic synthetic chemistry.

3. The Necessity of Applying the Collaborative Education Model of Science, Education, and Industry to Inorganic Synthetic Chemistry Course Teaching

3.1. Aligning with Discipline Development and Talent Cultivation Needs

The development of inorganic synthetic chemistry relies heavily on scientific innovation and its close integration with industrial applications. Through the collaborative education model of science, education, and industry, scientific research achievements can be promptly translated into teaching content, allowing students to access cutting-edge knowledge in the field. Simultaneously, teaching can be closely aligned with the practical needs of the industry, cultivating high-quality chemistry professionals who possess not only a solid theoretical foundation but also practical skills and an innovative spirit. This approach meets the talent requirements for discipline development and addresses the diverse needs of society for professionals in related fields.

3.2. Enhancing Students' Comprehensive Competence and Employability

Under this model, students have the opportunity to participate in scientific research projects and engage deeply in industrial practices. This enables them to hone their hands-on skills, innovative thinking, and teamwork abilities in real-world settings, thereby gaining a better understanding and mastery of the application of inorganic synthetic chemistry knowledge. Upon graduation, they can adapt more quickly to their roles, whether they choose to further their studies in research institutions or pursue careers in industries such as chemical engineering and materials, engaging in production, research, and development. This model equips them with stronger competitiveness and lays a solid foundation for their career development.

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3.3. Promoting Collaboration and Mutual Benefits among Universities, Research Institutions, and Industry

Universities can leverage the research capabilities of scientific institutions to enhance their own research levels, while optimizing talent cultivation programs and expanding practical teaching resources through collaboration with industry. Research institutions can jointly cultivate talent with universities, thereby building a reserve of future professionals for their own development, and simultaneously translating scientific achievements into practical applications through industry. Industry, in turn, gains access to high-quality talent that meets its needs, as well as technical support from universities and research institutions, driving industrial upgrading and innovative development. This creates a win-win-win scenario for all three parties.

4. Optimization and Integration of Inorganic Synthetic Chemistry Course Content from the Perspective of Collaborative Education in Science, Education, and Industry

4.1. Incorporating Cutting-Edge Scientific Research Achievements

4.1.1. Tracking the Latest Development in the Discipline

Teachers should regularly review authoritative academic journals, attend academic conferences, and stay updated on the latest research trends in inorganic synthetic chemistry [2]. This includes advancements in the synthesis methods of novel inorganic functional materials (such as two-dimensional materials and quantum dots), green synthesis processes, in-situ synthesis techniques, and other emerging areas. These cutting-edge knowledge can be integrated into the course content through specialized lectures, case studies, and other forms, enabling students to understand the forefront of the discipline, broaden their knowledge base, and stimulate their interest in learning and innovative thinking.

4.1.2. Integrating Research Project Case Studies

Teachers should refine and transform their own research projects or collaborative inorganic synthesis projects with research institutions into teaching case studies. When explaining relevant synthesis principles and methods, these cases can be introduced to analyze the synthesis objectives, technical routes, challenges encountered, and solutions in detail. For example, when introducing hydrothermal synthesis, a case study on the synthesis of novel nanomaterials using hydrothermal methods in a research project can be incorporated. This helps students understand how to design hydrothermal synthesis conditions based on material performance requirements and how to characterize and analyze the products. Through real-world case studies, students can better grasp theoretical knowledge and improve their ability to apply knowledge to solve practical problems.

4.2. Strengthening Connections with Industrial Applications

4.2.1. Incorporating Industrial Case Studies

Collect and integrate application case studies of Inorganic Synthetic Chemistry in related industries such as chemical engineering and materials. Examples include the synthesis and processing of semiconductor materials in the electronics industry, the synthesis of lithium battery cathode materials in the new energy industry, and the synthesis of high-performance inorganic insulation materials in the construction materials industry. In the course teaching, these industrial cases can be interwoven with different synthesis methods and key points, analyzing their production processes, quality control key points, and market demands. This helps students understand the practical application scenarios of the inorganic synthesis knowledge they have learned, enhances their understanding of industrial realities, and improves their professional adaptability.

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4.2.2. Introducing Enterprise Standards and Specifications

Invite industry experts to participate in course content design and integrate technical standards, operating procedures, and quality inspection standards from enterprises into the teaching process. For example, when introducing the synthesis of a certain inorganic compound, explain the specific requirements of enterprises for raw material purity, reaction temperature, pressure, and other parameters, as well as the indicators and methods for product quality inspection. This allows students to familiarize themselves with enterprise work standards and requirements in advance, cultivating professional competence that aligns with the actual needs of the industry.

5. Application of Diversified Teaching Methods in Inorganic Synthetic Chemistry Courses from the Perspective of Collaborative Education in Science, Education, and Industry

5.1. Problem-Based Learning (PBL)

5.1.1. Problem Design and Presentation

Teachers design a series of thought-provoking and exploratory questions based on the course content and real-world application scenarios [3]. For example, when teaching high-temperature synthesis methods, questions such as "How to select the appropriate type of high-temperature furnace and control reaction conditions to improve the purity and performance of a new ceramic material?" or "What are the main technical challenges currently faced in high-temperature synthesis of such materials, and how can these issues be addressed by improving synthesis methods?" can be posed. These questions guide students to think critically and stimulate their desire for active exploration.

5.1.2. Student-Led Inquiry and Group Discussion

Students are divided into groups to research the questions, conduct group discussions, analyze the causes of the problems, and attempt to propose solutions. In this process, students need to apply their knowledge of inorganic synthetic chemistry and extend it to related disciplines, fostering their self-directed learning ability, comprehensive knowledge application skills, and teamwork capabilities. For instance, to address the aforementioned questions about high-temperature synthesis of ceramic materials, students may research the types and performance of high-temperature furnaces, the structural and performance requirements of ceramic materials, and the kinetics of high-temperature chemical reactions. They then engage in in-depth group discussions to share their insights and ideas.

5.1.3. Teacher Guidance and Summary Feedback

During the student-led inquiry and group discussion process, teachers should provide timely guidance to help students organize their thoughts, focus on key points, and avoid straying from the topic. After presenting their discussion results, teachers should evaluate and summarize their proposed solutions, highlight strengths and weaknesses, and guide students to further refine their ideas. Teachers should also connect the problem-solving process to the core knowledge of the course, deepening students' understanding and mastery of the subject matter.

5.2. Blended Online and Offline Teaching Methods

5.2.1. Development of Online Teaching Resources

Utilize online teaching platforms (such as Chaoxing Learning Platform, Zhihuishu, etc.) to build a repository of online teaching resources for the Inorganic Synthetic Chemistry course [4]. This includes teaching slides, instructional videos (recorded lectures, experimental demonstrations, etc.), online quizzes, supplementary reading materials (academic papers, industry reports, etc.), and discussion forums. Students can access these resources anytime and anywhere to study course content, take self-assessments, and participate in discussions, breaking the time and space constraints of traditional teaching and facilitating preview, review, and extended learning.

5.2.2. Interactive Offline Classroom Teaching

In offline classroom teaching, teachers focus on addressing common issues encountered by students during online learning, providing detailed explanations and Q&A. Teachers can organize classroom discussions, group collaborative learning, and experimental activities to enhance face-to-face interaction between teachers and students, as well as among students. For example, teachers can showcase representative questions raised by students in the online discussion forum, guiding the class to analyze and discuss them collectively. Alternatively, teachers can organize students into groups for experimental operations, providing on-site guidance and feedback to improve students' hands-on skills and deepen their understanding of the knowledge.

5.2.3. Integration and Optimization of the Teaching Process

By combining online and offline teaching methods, the teaching process can be optimized. Online learning serves as a foundation for offline classroom teaching, improving classroom efficiency, while offline teaching compensates for the lack of interaction in online learning and further expands on the online content. Teachers should appropriately arrange the proportion of online and offline teaching content and activities based on course objectives and students' learning progress, leveraging the strengths of both approaches to enhance overall teaching quality.

6. Conclusion

The reform of the Inorganic Synthetic Chemistry course teaching model from the perspective of collaborative education in science, education, and industry has facilitated the deep integration and complementary advantages of resources among universities, research institutions, and the industrial sector, fostering a close collaborative relationship. This reform has strengthened the disciplinary development of universities, improved the transformation rate of research outcomes of research institutions, and provided the industrial sector with high-quality talent and technical support, creating a mutually beneficial and win-win situation. This model is worthy of further promotion, application, and in-depth research and refinement in the fields of chemistry and related disciplines.

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References

[1] J. Qin, C. Xiao, S. Liu, et al: Exploration and practice of environmental engineering major construction based on the integration of science, industry and education model, Journal of Higher Education Teaching, Vol. 1(2024) No.6, p.254-259.

[2] Q. Wang, and Z. Liu: The advanced results are integrated into the teaching of inorganic chemistry, Advances in Higher Education, Vol. 8(2024) No.5, p.198-200.

[3] W. Guo: Application of "PBL" teaching mode in inorganic chemistry experiment teaching, Advances in Higher Education, Vol. 7(2023) No.1, p.210-212.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202505_8(5).0009

[4] C. Xiao, H. Cai, Y. Su, et al: Online teaching practices and strategies for inorganic chemistry using a combined platform based on DingTalk,Learning@ZJU, and WeChat, Journal of Chemical Education, Vol. 97(2020) No.9, p.2940-2944.