Journal of Contemporary Educational Research, 2025, Volume 9, Issue 12
http://ojs.bbwpublisher.com/index.php/JCER
ISSN Online: 2208-8474
ISSN Print: 2208-8466

Research on Teaching Reform of the Course "Chemical Instrumentation and Automation" under the Background of Integration of Specialization and Innovation

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Abstract: This paper focuses on the teaching reform of "Chemical Instrumentation and Automation" under the background of the integration of specialization and innovation. Currently, the course faces several problems, such as teaching content lagging behind the needs of industrial intelligence, rigid teaching models with weak practical innovation, and insufficient innovative literacy and engineering capabilities of teachers. The research points out that teaching reform is the core path to cultivate innovative chemical engineering talents, meet the intelligent development of the industry, and enhance the professional competitiveness of universities. To this end, countermeasures are proposed, including reconstructing a three-step curriculum system of "basic theory + cutting-edge technology + innovative application," building a "teaching-practice-innovation" teaching model and a diversified practical platform, strengthening the construction of a "double-qualified" teaching team, and improving an innovation-oriented comprehensive evaluation system. The aim is to realize the in-depth integration of professional education and innovative education, and deliver compound practical talents for the transformation and upgrading of the chemical industry.

Keywords: Integration of specialization and innovation; Chemical instrumentation and automation; Teaching reform

Online publication: December 31, 2025

1. Introduction

With the deep integration of manufacturing and information technology, the chemical industry is rapidly transforming towards intelligence and greenization. Emerging high and new technologies, such as the industrial internet and intelligent algorithms, have put forward new requirements for the professional quality of practitioners. As a core discipline in chemical processes, the traditional teaching method of "Chemical Instrumentation and Automation" is theory-oriented, with defects such as outdated knowledge and disconnection from practice, which are not conducive to cultivating students' practical work abilities.

How to carry out educational reform based on the organic combination of professionalism and creativity is a problem that educators need to consider. How to naturally embed creative elements into the teaching structure in line with industrial development needs, so as to cultivate compound talents meeting the needs of industry development, plays a decisive role in the teaching level and competitive advantage of the chemical engineering major in universities, as well as in the upgrading and development of the chemical industry. This paper makes an exploration in this regard, explains the necessity of reform, clarifies the existing problems in the current situation, and puts forward corresponding solutions.

2. Significance of teaching reform in Chemical Instrumentation and Automation under the background of integration of specialization and innovation

2.1. Teaching reform under the background of integration of specialization and innovation is the core path to cultivate innovative talents in the chemical industry

In the traditional teaching mode of the "Chemical Instrumentation and Automation" course, teachers usually adopt a one-way indoctrination method, focusing on basic theories such as instrument working principles and mechanical structures [1]. This single knowledge transmission method is prone to rigidifying students' thinking and makes it difficult to cultivate their abilities of active exploration and creative problem-solving. The new educational model based on the integration of specialization and innovation aims to break this limitation by integrating innovative elements into the professional curriculum system. In the specific implementation of teaching reform, the original curriculum structure will be systematically adjusted, with additional open experiments and project-based learning sessions. Taking instrument calibration and process control as examples, instead of providing standardized operating procedures, teachers require students to independently design test schemes and compare the actual effects of different control algorithms. This teaching transformation can not only improve students' professional skills but also cultivate their systematic thinking and interdisciplinary integration capabilities, laying a solid foundation for nurturing compound talents adapting to the development of the chemical industry [2].

2.2. Teaching reform is an inevitable requirement to meet the intelligent development needs of the chemical industry

Against the backdrop of the deep integration of manufacturing and information technology, the chemical industry is accelerating its evolution towards intelligence and greenization, which poses new challenges to the professional quality of practitioners. The current curriculum system of "Chemical Instrumentation and Automation" has an obvious lag, with teaching content seriously disconnected from industrial practice. Graduates often need a long time to adapt to the actual working environment [3–5]. Teaching innovation based on the concept of integration of specialization and innovation can effectively connect the context of industrial technological development, organically integrating emerging technologies such as industrial internet of things, intelligent algorithms, and data mining into the curriculum system. By adding modules such as intelligent instrument application, control system upgrading and transformation, and digital monitoring of production processes, students are helped to grasp the cutting-edge technological trends of the industry and core job competencies. In addition, this reform specifically emphasizes cultivating students' ability to apply innovative technologies to solve engineering practice problems, realizing the precise alignment between teaching content and industrial needs. It delivers compound talents with practical capabilities for the transformation and upgrading of the chemical industry, effectively alleviating the shortage of high-skilled talents faced in the process of industrial upgrading [6].

2.3. Teaching reform is an important measure to improve the teaching quality and competitiveness of chemical engineering majors in universities

The quality of education is the lifeline of higher education, and classroom teaching is the primary link to improve quality. The teaching reform of the "Chemical Instrumentation and Automation" course under the background of integration of specialization and innovation is not only a change in curriculum content and teaching methods but also a new exploration of teaching concepts and talent training models. It promotes interdisciplinary development and constructs mechanisms for the use and sharing of interdisciplinary resources. For example, joint teaching with other disciplines such as computer science and electronic science and engineering enriches teaching resources and broadens students' horizons. At the same time, it forces the teaching team to grow, establishes the teaching concept of lifelong learning, improves their teaching level, innovates teaching methods, and increases engineering practice experience. In addition, the educational reform taking the integration of specialization and innovation as the entry point can enhance the attractiveness and social recognition of the discipline and major, strengthen the social competitiveness of chemical engineering-related majors in universities, and also provide support for the university's strategy of "professional category training—solid foundation and broad caliber—professional diversion talent training program and in-depth continuous development."

3. Problems existing in the traditional teaching of Chemical Instrumentation and Automation in universities

3.1. Outdated teaching content and disconnection from innovation needs

At present, the teaching content of Chemical Instrumentation and Automation in universities is obviously outdated, failing to meet the requirements of knowledge renewal and innovative competence cultivation under the integration of specialization and innovation. On the one hand, the teaching content is still dominated by traditional instrument principles and classic control theories, failing to fully incorporate the trends of the latest technological development. As the chemical industry moves towards intelligence and digitalization (emerging technologies such as industrial internet, artificial intelligence, and edge computing have been integrated into equipment selection, control scheme optimization, and production monitoring processes), the current teaching materials and syllabuses do not treat these new technologies as a complete knowledge structure system. This makes it difficult for students to timely and comprehensively master the emerging core skills in this field [7]. On the other hand, the teaching content focuses on the completeness of theory rather than the practicality of application. Much of the content remains in answering "what" and "why," with little discussion on issues such as "how to apply innovatively" and "how to solve complex engineering problems." The cultivation of innovative and entrepreneurial thinking is not integrated into the knowledge transmission process, making it difficult for students to transform the learned knowledge into innovative capabilities. This deviates from the goal of the integration of specialization and innovation that "innovation is the driving force for learning and development, and the key to improving abilities and qualities."

3.2. Rigid teaching model and weak practical innovation links

The traditional and rigid classroom teaching model has imposed many restrictions on the promotion of the integration of specialization and innovation, especially the lack of student innovation in practical learning links is particularly prominent. In many theoretical classes, the one-way indoctrination model of "teacher lecturing + students listening" is still maintained. Students can only accept knowledge passively, lacking sufficient space for their own thinking, questioning, and inquiry. It is thus difficult to effectively cultivate students' critical and creative thinking abilities. In practical training links, there are also drawbacks of "valuing verification over design and procedures over innovation." Many experiments are conducted to verify a certain knowledge point or theory, rather than cultivating students' ability to design their own plans or seek optimized experimental schemes. Meanwhile, most internship opportunities are limited to the virtual environment of the university, making it difficult for students to have actual contact with the real environment of industrial production processes. Students lack platforms to access innovative technologies in fields such as new measurement tools and automatic control in real scenarios. In addition, the shortage of practical learning resources is one of the key factors contributing to the problem. Due to limited funds, some universities cannot update laboratory equipment in a timely manner, nor do they have sufficient funds to build intelligent laboratories that support students' innovative practical skills, leading to many deficiencies in the cultivation of practical and innovative skills.

3.3. Insufficient innovative literacy and engineering practice capabilities of teachers

Teachers are the main force in promoting the teaching reform of the integration of specialization and innovation. Their insufficient innovative literacy and engineering practice capabilities seriously restrict the effectiveness of the reform. On the one hand, teachers focus more on theoretical teaching tasks and lack sufficient engineering practice experience. They have no direct perception of the latest engineering technology applications in the industrial sector, the competency requirements of professional positions, and the new trends of innovative development. Therefore, it is difficult for them to organically connect professional knowledge with engineering innovation applications in the teaching process, nor do they have the literacy to guide students in transforming theoretical knowledge into innovative practical application capabilities. On the other hand, teachers are not proficient in mastering innovative teaching methods [8]. Some teachers still use traditional teaching and evaluation methods, and have insufficient understanding of teaching methods that cultivate students' innovative thinking, such as project-based learning, case teaching, and flipped classrooms. In curriculum design, teachers lack purposeful and systematic training plans for cultivating students' innovative thinking and entrepreneurial awareness, making it difficult to stimulate students' innovative potential through teaching activities.

4. Teaching reform countermeasures for Chemical Instrumentation and Automation in universities under the background of integration of specialization and innovation

4.1. Reconstructing the curriculum content system to realize the organic integration of professional and innovative knowledge

Reforming curriculum content is a key measure for teaching reform, which requires breaking the original knowledge system and constructing a dynamically updated, interdisciplinary, integrated knowledge system. Firstly, keep pace with industrial technological changes in a timely manner, add cutting-edge knowledge modules, integrate emerging technologies such as industrial internet, AI, and digital twins into in-depth learning modules of chemical instrumentation and automation, develop new learning modules such as "Application of Intelligent Instruments," "Intelligentization of Control Systems," and "Intelligent Monitoring of Production Systems," and build a three-step curriculum content system of "basic theory + cutting-edge technology + innovative application." Secondly, attach importance to the innovative application of knowledge and increase the proportion of design-oriented and exploratory experiments. While retaining certain core theoretical knowledge, reduce pure principle explanation and strengthen the introduction of "problem-oriented" knowledge. For example, aiming at quality control issues in chemical plants, guide students to think about what equipment to select, how to formulate control schemes, and conduct innovative solutions. Integrate knowledge from other fields and set up interdisciplinary courses with disciplines such as computer science and technology, electronic technology, such as "Image Analysis in Analytical Chemistry" and "Programming and Application of Computer Instrument Software," to expand students' knowledge scope and multi-dimensional thinking abilities.

4.2. Innovating teaching modes and practical platforms to strengthen the cultivation of students' innovative and practical abilities

Transform the traditional teaching mode, construct a "teaching-practice-innovation" teaching model, and establish diversified experimental and training bases. Firstly, in the theoretical teaching link, carry out interactive and inquiry-based teaching. Decompose the curriculum content into multiple small practical engineering projects, such as "Design and Implementation of Automatic Control for a Small Chemical Plant" and "Fault Diagnosis of Measuring Equipment and Selection of Schemes." Organize students in small classes into experimental groups to complete the entire project process, cultivating their teamwork abilities as well as their capabilities of creative analysis and problem-solving. Secondly, reform the original experimental teaching, shifting from "verification-oriented" to "design-oriented and innovative." Add experimental projects with high complexity and difficulty in the practical link, such as "Experiment on Chemical Parameter Prediction and Control Using Machine Learning Technology" and "Optimal Design Experiment of Controllers with Multiple Interacting Factors," encouraging students to independently design experimental schemes, select experimental equipment, and analyze experimental results. Build an "in-class and after-class" collaborative education platform, develop intelligent and simulation-based laboratories in the college, and purchase simulation technologies to simulate complex chemical production processes and the operation of precision instruments, making up for the shortage of physical equipment. Cooperate with chemical enterprises to build off-campus internship and training bases, regularly organize students to work in front-line factory positions, participate in practical work such as process optimization, system maintenance, and technological transformation, and improve their practical abilities in real engineering project environments [9].

4.3. Strengthening the construction of teaching staff to improve teachers' teaching capabilities in the integration of specialization and innovation

Building a teaching team with profound knowledge, rich engineering practice experience, and solid innovative educational methods is a key factor in ensuring educational innovation. Firstly, establish a training system to enhance teachers' engineering practice capabilities, and implement the "double-qualified teacher" training project. Encourage teachers to intern in chemical enterprises, participate in corporate R&D projects, gain an in-depth understanding of the technological development trends of the chemical industry and enterprise requirements for engineering, and improve their engineering practice capabilities. It is also feasible to hire technical personnel and engineers from chemical enterprises as part-time teachers for school courses, organizing them to participate in classroom teaching, internship, and experiment guidance, and project design achievement evaluation, thereby introducing the latest cutting-edge technological concepts and practical cases into the teaching process. Secondly, improve the training mechanism for teachers to carry out innovative educational technologies. Regularly organize special training for teachers on innovative teaching methods, such as workshops on project-based learning and case-based engineering practice teaching, enabling them to master the latest teaching theories and methods. Organize teacher seminars to discuss and formulate new teaching methods, curriculum systems, and practical project settings, strengthening experience exchange among teachers. Encourage teachers to participate in scientific research activities related to innovation and entrepreneurship education, explore the educational and teaching laws and strategies for integrating professional education with innovative education, and improve their teaching and research literacy. Thirdly, establish a teacher evaluation and reward mechanism. Incorporate factors such as the time, energy, and work achievements invested by teachers in the integration of specialization and innovative teaching, their actual social and enterprise work experience, and the innovation and entrepreneurship achievements of the students they guide into the teacher performance evaluation system. Provide reasonable rewards or professional title promotions based on their work performance, so as to fully mobilize their enthusiasm and initiative in educational and teaching reform.

4.4. Improving the teaching evaluation system and establishing innovation-oriented evaluation standards

Change the previous single-dimensional evaluation method, construct a diversified and process-oriented teaching evaluation system, with particular emphasis on the evaluation of students' creativity. Firstly, expand the evaluation content and requirements. Evaluate students' innovative thinking, practical operation, and project achievements, forming a comprehensive evaluation standard of "knowledge mastery + skill application + innovative achievements." This can cover unique aspects in students' activity design, specific effects of project practice activities, and partial achievements such as research papers or patents, changing the score-oriented evaluation model. Secondly, adopt a comprehensive evaluation method that combines process evaluation with summative evaluation. In the process evaluation, reflect the growth trajectory of students' learning and innovative capabilities through the assessment of learners' behavioral performance, team interaction, practical project reports, and practical process records. Comprehensive evaluation breaks through the limitations of traditional written tests and can be completed in forms such as thesis defense, product display, and practical operation assessment, allowing students to demonstrate their independent thinking and operational capabilities while presenting their learning achievements [10]. At the same time, increase the diversified evaluation subjects. In addition to teacher evaluation, self-evaluation, intra-group mutual evaluation, and enterprise teacher participation in evaluation should be included. This enables a multi-angle understanding of students' learning effects and innovative capabilities, ensuring the fairness and completeness of the evaluation. Improving educational and teaching evaluation can shift the focus of learning from "rote learning" to "application and innovation," better arouse students' innovative potential, and achieve the educational goal of cultivating innovative talents.

5. Conclusion

The teaching reform of the integration of specialization and innovation is an inevitable requirement to adapt to industrial transformation and cultivate innovative graduates. It requires university teachers to reconstruct the curriculum system, strengthen the construction of teaching staff, optimize the evaluation system, and break through the constraints of traditional teaching. Teaching reform is not only a reform at the curriculum level but also a major transformation of talent training concepts. It provides a platform for shifting from theoretical learning to practice and injects development vitality into the chemical and biological disciplines of universities.

Funding

Specialized and Innovative Integration Curriculum Construction Project of Inner Mongolia University of Technology (ZC2024007)

Disclosure statement

The authors declare no conflict of interest.

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