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Innovative Reform of Blended Teaching in Environmental Reaction Engineering Course

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Abstract: To meet the requirements for cultivating environmental engineering talents in the construction of new engineering, engineering education accreditation, and the “dual carbon” strategy, a blended teaching model of “three-stage, four-integration, and multi-dimensional evaluation” is constructed to address the pain points in the “Environmental Reaction Engineering” course, such as the disconnection between theory and practice, insufficient cultivation of high-order abilities, rigid integration of ideological and political education into the curriculum, and inefficient use of information resources. Through the four integrations of theory and engineering application, online and offline, customized and non-customized, and ideological and political education and professional knowledge, relying on the online platform, engineering case library, and diversified evaluation system, a whole-process education path of “pre-class self-learning-in-class collaborative construction-post-class expansion and innovation” is formed.

1. Introduction

“Environmental Reaction Engineering” is a core course in the environmental engineering major. It combines strong theoretical and high engineering characteristics and is a key link connecting basic chemical principles and environmental engineering practice. With the continuous advancement of new engineering construction, the deepening of engineering education accreditation, and the new requirements for environmental talents put forward by the “dual carbon” strategy, the traditional classroom teaching method can hardly meet the talent cultivation goals in the new era. In teaching practice, the course has exposed problems such as the prominent contradiction between the complex content and limited class hours, the disconnection between theoretical teaching and engineering practice, the weak cultivation of high-order abilities, the formal integration of ideological and political education into the curriculum, and the low utilization efficiency of information teaching resources, which restrict the improvement of teaching quality and educational effectiveness. To solve the above pain points, this research is based on the OBE educational concept, centered on students and outcome-oriented. Relying on the technological advantages of "Internet+education", the curriculum teaching system is reconstructed, teaching methods and evaluation models are innovated, and a curriculum reform path suitable for the cultivation needs of new engineering talents is explored, aiming to cultivate compound environmental engineering talents with a solid professional foundation, strong engineering practice ability, innovative thinking, and social responsibility[1-2].

2. Main Existing Problems in Curriculum Teaching

2.1 The Theoretical System Is Complex and There Is Insufficient Cultivation of Advanced Skills

The course covers many contents such as reaction kinetics, reactor design, mass transfer coupling, and process optimization. The knowledge points are abstract and the system is huge. With the continuous reduction of class hours, teaching mostly stays at the level of theoretical indoctrination. Students passively receive formulas and principles, lacking the process of independently constructing a knowledge system. They have difficulty applying theories to real engineering scenarios such as wastewater treatment and flue gas purification, resulting in the dilemma of "understanding theories but not knowing how to use them".

Engineering education emphasizes cultivating students' abilities to solve complex engineering problems, innovative design, and high-order thinking, requiring the course to have high-order, innovative, and challenging characteristics [3]. Traditional teaching focuses on knowledge memory and simple calculations, lacking in-depth exploration links such as complex case analysis and scheme optimization design. Students are in a passive learning state for a long time, with weak innovation awareness. When facing engineering problems with multi-factor coupling, their analysis, judgment, and problem-solving abilities are insufficient.

2.2 The Integration of Ideological and Political Education into the Curriculum Is Rigid, and the Utilisation of Information Technology Resources Is Inefficient

In the new era, higher education takes "cultivating virtues and educating people" as the fundamental task, and professional courses are an important carrier of ideological and political education in the curriculum [4]. In previous teaching, ideological and political education was mostly integrated in a slogan-like and additional way, separated from professional knowledge. Ideological and political elements such as green development, ecological civilization, engineering ethics, and serving the country through science and technology were not deeply explored. The value guidance was separated from knowledge imparting and ability cultivation, and the educational value was not fully highlighted.

Internet technology provides rich information resources for teaching. However, in the traditional model, online resources and offline classrooms are independent of each other, only serving as a supplement after class, without forming a systematic connection. Students lack a clear path for pre-class preview, and there are no targeted tasks for post-class consolidation. Teachers cannot grasp students' learning effects in real-time, and teaching feedback is lagged. The initiative, continuity, and effectiveness of students' self-learning are greatly reduced.

3. Innovative Concepts and Core Measures of Curriculum Reform

3.1 Reform Concept

This curriculum reform focuses on the teaching pain points, is based on the requirements for cultivating new engineering talents, integrates the OBE educational concept (Figure 1), and is led by “Internet+education” to construct a blended teaching model of “three-stage, four-integration, and multi-dimensional evaluation”[1-2]. Relying on the Chinese University MOOC, intelligent teaching platform, and engineering case resource library, a whole-process education system of “pre-class self-learning-in-class collaborative construction- post-class expansion and innovation” is created. Through the four integrations, the barriers of traditional teaching are broken, and the three-dimensional goals of knowledge, ability, and quality are achieved synergistically.

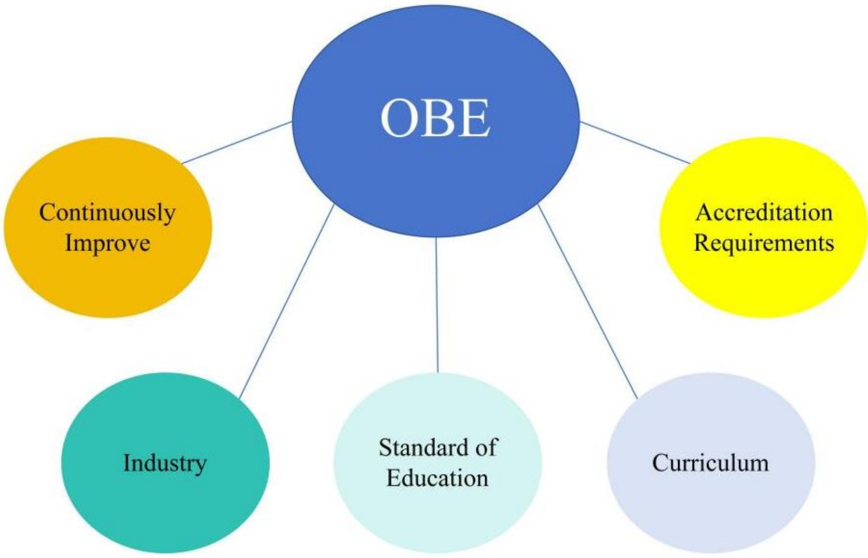

Figure 1: OBE Educational Philosophy.

3.2 Using Cases as a Medium to Promote the Integration of Theoretical Knowledge and Engineering Application

According to the typical process design logic of environmental engineering, the teaching content is reconstructed into four modules: “reaction kinetics analysis- reactor characteristic analysis-process intensification design- engineering optimization application”, realizing the precise correspondence between theory and engineering processes[5]. A multi-case library covering teachers’ scientific research achievements, students’ innovation and entrepreneurship projects, and industry benchmark projects is established, covering fields such as wastewater treatment, flue gas desulfurization and denitrification, catalytic oxidation, and solid waste resource utilization. The teaching path of “case introduction-theoretical analysis-model construction-engineering decision-making” is adopted, using cases to connect knowledge points and guiding students to use theories to solve real engineering problems. At the same time, a mechanism of “scientific research feeding back teaching” is established, integrating scientific research achievements and disciplinary frontiers into the classroom to broaden students’ academic horizons[6].

3.3 Complementary Advantages to Achieve the Integration of Online Teaching and Offline Classrooms

According to Bloom's cognitive goal classification theory, the course knowledge is divided into low-order cognition (memory, understanding, simple application) and high-order cognition (analysis, evaluation, creation), matching different teaching scenarios[7].Online teaching focuses on low-order cognition, building a complete resource system including micro-courses, electronic courseware, animation demonstrations, and online tests. The micro-courses are controlled within 10-15 minutes for fragmented learning. Students complete online learning before class to consolidate the foundation. Offline teaching focuses on high-order cognition, using models such as flipped classrooms, PBL, and group discussions to conduct in-depth exploration around complex engineering cases, cultivating students' analysis, collaboration, and innovation abilities. Relying on the intelligent platform to collect learning data, a learning portrait is formed to achieve precise teaching.

3.4 Empowering in Layers to Promote the Integration of Customized Learning and Non-Customized Learning

Respecting students' individual differences, a dual-line learning system of "customized content+non-customized content" is constructed. The customized content is for all students, focusing on core theories such as reaction kinetics and reactor design. Through online micro-courses, offline in-depth explanations, and basic exercises, students are ensured to meet the basic goals. The non-customized content is for students with spare capacity, covering frontier literature analysis, scientific research paper reading, innovative product design, and competition preparation. Layered exploration tasks are set to connect the classroom with the second classroom. Projects of innovation and entrepreneurship and disciplinary competitions are incorporated into the cultivation system, promoting students to transform from knowledge learners to creators.

3.5 Value Guidance to Promote the Integration of Ideological and Political Education and Professional Cultivation

Adhering to the trinity goal of "value shaping, knowledge imparting, and ability cultivation", ideological and political elements in the curriculum are deeply explored, and concepts such as green development, ecological civilization, the "dual carbon" strategy, engineering ethics, craftsmanship spirit, and serving the country through science and technology are integrated into the whole teaching process. Ideological and political content is naturally integrated with knowledge points. By explaining environmental protection engineering achievements, students' national pride is enhanced. By reviewing engineering accident cases, students' sense of responsibility is strengthened. By introducing the deeds of scientists, the scientific research spirit is promoted. Special discussions such as "Serving the Country through Science and Technology, I'm Committed to Environmental Protection" are set up to guide students to establish the ideal and belief of serving the country's ecological civilization construction.

4. Teaching Implementation Process

4.1 Pre-class: Online Self-Learning to Consolidate the Foundation

Teachers release learning guides, task lists, and online resources through the intelligent platform one week in advance. Students independently learn theories such as heterogeneous reaction mass transfer, diffusion, and reaction coupling, and complete in-class tests to check for gaps and make up for deficiencies. They form groups of 4-5 people to sort out knowledge points, conduct preliminary discussions, form summary reports, and identify difficult problems to prepare for classroom learning.

4.2 In-Class: Offline Collaborative Construction to Improve Abilities

The 90-minute class focuses on high-order abilities and is carried out in four steps: ① Knowledge review (20 minutes):Check the online learning effect through group reports and quizzes, and sort out common problems;② Case review (30 minutes): Focus on the case of "optimized design of heterogeneous catalytic reactors", guiding students to sort out influencing factors and build logical chains; ③ Group collaborative design (30 minutes): Each group discusses and optimizes the design, and teachers patrol and guide; ④ Comment and summary (10 minutes): Each group presents the design, teachers comment, and self-evaluation and mutual evaluation are organized to achieve cognitive leap.

4.3 Post-Class: Expansion, Innovation, and Practice, and Achievement Transformation

Excellent classroom cases and design schemes are sorted out to form an expansion resource library, and layered tasks are assigned: the basic level completes regular exercises, the improvement level writes case analysis reports, and the expansion level participates in innovation practice. An innovation achievement recognition mechanism is established, and achievements in innovation and entrepreneurship projects, competitions, and scientific research are included in the evaluation to promote the transformation of knowledge into abilities. The teaching implementation process is shown in Figure 2.

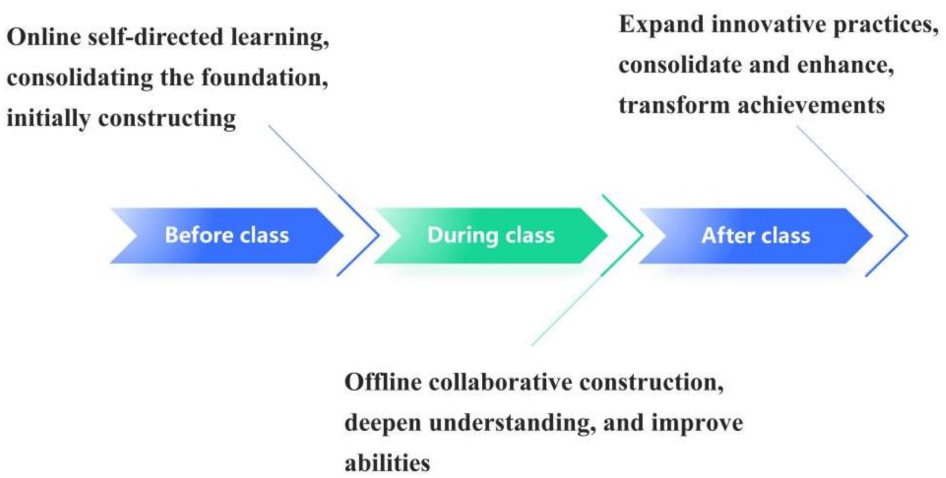

Figure 2: Teaching process.

5. Curriculum Evaluation System and Reform Achievements

Breaking the "one-exam-determines-the-grade" model, a comprehensive evaluation system that is process-oriented and ability-oriented is constructed: ① Knowledge goal evaluation (40%): Online learning data + final theoretical exam; ② Ability goal evaluation (35%): Classroom discussions, group designs, and practical performance; ③ Value shaping evaluation (15%): Ideological and political performance, learning attitude, and sense of responsibility; ④ Innovation achievement evaluation (10%): Bonus points for achievements in innovation and entrepreneurship projects, competitions, and scientific research. The diversified comprehensive evaluation system is shown in Figure 3.

Since the implementation of the teaching reform, the curriculum teaching evaluation has been rated excellent for many consecutive years, and students' classroom participation and learning enthusiasm have been significantly improved[5]. The analysis of the achievement of graduation requirements shows that students' four core abilities have been significantly enhanced: First, the ability to analyze and solve complex engineering problems has been significantly improved; Second, the engineering design and comprehensive application abilities are outstanding; Third, the innovation practice and scientific research abilities have been enhanced, and many students have participated in scientific research, published papers, and won competition awards; Fourth, the habit of self-learning and lifelong learning has been developed. The reform has effectively achieved the talent cultivation goal of "understanding knowledge, being able to analyze, being capable of practice, having a sense of responsibility, and daring to innovate".

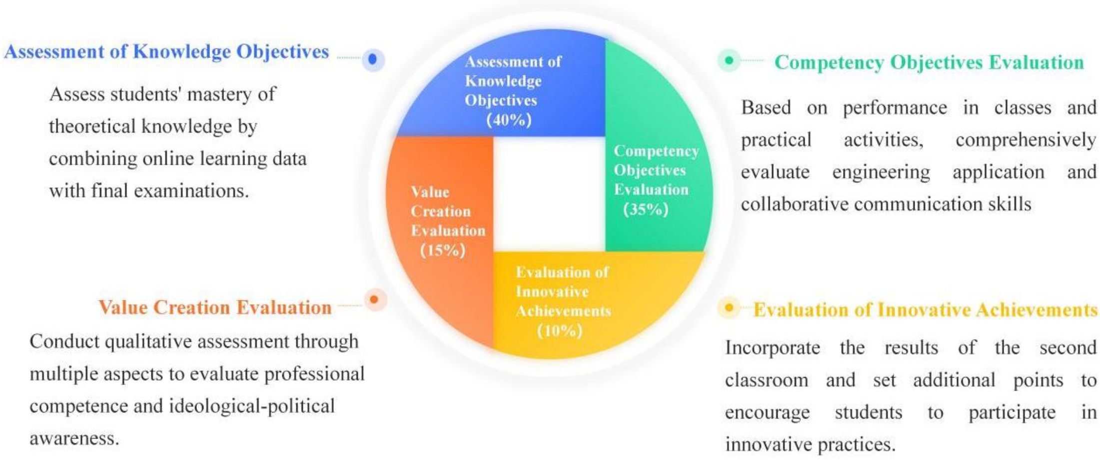

Figure 3: Diversified comprehensive evaluation system.

6. Application Promotion and Continuous Improvement

The curriculum reform has formed a complete and replicable teaching system, including an online resource library, an engineering case library, a blended teaching plan, a diversified evaluation system, and an ideological and political case library, which can be directly applied to core courses in environmental and chemical engineering majors and is suitable for the reform of similar engineering courses. The relevant achievements have been promoted in the core courses of multiple majors in the school with good results and can be promoted to similar institutions through teaching seminars, demonstration classes, and paper reports.

A regular teaching reflection mechanism is established to collect feedback from teachers and students regularly and dynamically optimize teaching content and resources. Keeping up with the development trends of the industry and education, cases and frontier content are updated. In the future, three aspects of work will be mainly promoted: First, introduce artificial intelligence-assisted teaching to achieve personalized recommendation and intelligent Q&A; Second, upgrade digital resources and enrich virtual simulation experiments; Third, improve the four-in-one education model of "online+offline+practice+innovation" to continuously improve the quality of talent cultivation.

7. Conclusion

In response to the teaching pain points of the "Environmental Reaction Engineering" course, this reform is based on the requirements of new engineering and engineering education accreditation. The constructed blended teaching model of "three-stage, four-integration, and multi-dimensional evaluation" effectively solves the problems of the disconnection between theory and practice, insufficient cultivation of high-order abilities, and rigid integration of ideological and political education. The whole-process education path and diversified evaluation system fully stimulate students' learning initiative and significantly improve students' engineering practice ability, innovative thinking, and comprehensive quality. This reform model has strong practicality and promotion value and can provide a reference for the teaching reform of engineering courses in the new era, helping to cultivate high-quality environmental engineering talents serving the country's ecological civilization construction.

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