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Construction and Implementation of the Hybrid Teaching Model: An Exploration of Curriculum Development in the Water Pollution Control Engineering Course

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Abstract: In order to actively promote high-quality educational informatization and strengthen green and low-carbon education, Heilongjiang University of Science and Technology has explored a hybrid online and offline teaching model in the "Water Pollution Control Engineering" course. This exploration is supported by the National Higher Education Smart Education Platform, adhering to a "knowledge goals + ability and quality goals + emotional and value goals" three-in-one construction philosophy. The course is closely aligned with industry needs, improves teaching resources, strengthens instructional design. In this study, an online and offline, in-class and out-of-class blended teaching model were constructed, and a diversified evaluation model was also established to strengthen the assessment of students' abilities, in order to meet the new requirements of talent training rich three-dimensional curriculum resources was built. This approach consolidates the knowledge base and enhances engineering practice skills. The hybrid model of the Water Pollution Control Engineering curriculum has been implemented across five academic years, showing significant educational outcomes.

Keywords: Water Pollution Control Engineering; Hybrid Teaching Model; Instructional Design; Green and Low-Carbon; Talent Cultivation

1. Introduction

The Ministry of Education's "Work Plan for Strengthening the Construction of Higher Education Talent Cultivation Systems for Carbon Peaking and Carbon Neutrality" has proposed that courses play a crucial role in improving the quality of talent cultivation, which poses new requirements for university educators in curriculum development [1-3].

"Water Pollution Control Engineering" at Heilongjiang University of Science and Technology is a core course in the nationally recognized Environmental Engineering program. It aligns with the university's focus on application-oriented talent cultivation and emphasizes a demand-oriented approach, highlighting the characteristics of the mining industry.

The course aims to develop students' abilities to apply engineering knowledge and technical principles to solve complex engineering problems in the field of water treatment. The curriculum development focuses on current societal and industry demands for water treatment through industry research, academic exchanges, student surveys, and discussions. It addresses three pressing issues: insufficient support from teaching methods for cultivating students' abilities to solve complex engineering problems, inadequate integration of ideological and political resources centered on "green and low-carbon" into the teaching content, and insufficient alignment of teaching content with the demands of the modern environmental protection industry, particularly in presenting new processes and technologies.

To address these issues, this study focuses on three aspects: enhancing ability cultivation [4,5], focusing on green and low-carbon principles, and aligning with industry needs. It aims to optimize instructional design, refine engineering cases [6-8], and improve the knowledge system and course resources [9,10], thereby deeply exploring and implementing the construction of the Water Pollution Control Engineering curriculum system, which include

four specific implementation measures as follows: Building the hybrid teaching model to create multi-channel talent cultivation paths. Establishing an "8+8" course content system. Building rich and multi-dimensional course resources to meet new talent cultivation requirements. Developing a "4+2" diversified evaluation model to strengthen student competency assessment.

2. Implementation Measures

During the construction of the Water Pollution Control Engineering course, a diverse, open, and multi-dimensional curriculum system was developed. This system combines online and offline learning, integrates in-class and extracurricular activities, and aligns theoretical teaching with engineering practices and the forefront of the discipline.

2.1 Strengthening Instructional Design: Building the Hybrid Teaching Model to Create Multi-Channel Talent Cultivation Paths

Relying on the Wisdom Tree platform, an online learning platform for the course was established, completing the construction of a shared online course and exploring and implementing a hybrid online and offline teaching model. Emphasizing practicality and applicability in alignment with course objectives, a hybrid talent cultivation platform combining "in-class + extracurricular" and "online + offline" was developed. This platform forms the "2T" (Two Channels and Two Platforms,2T) hybrid teaching model, consisting of "" (in-class and extracurricular) and "Two Platforms" (online and offline). The "2T" hybrid teaching design is shown in Figure 1.

Figure 1 illustrates the relationship between knowledge and ability cultivation. The red and blue colors represent online or offline classes, with blue representing the degree of cultivation, while pink signifies virtual simulation teaching. By integrating online and offline, in-class and extracurricular activities, the model unifies the "Virtual Simulation Classroom - Offline Classroom - Industry-Education Classroom - Academician Lecture Hall," achieving high-level ability cultivation from understanding to application to innovation.

In the implementation of the "2T" hybrid teaching model, multi-module teaching stages were set, each with a focus and complementing each other, forming a comprehensive talent cultivation path that spans online and offline, in-class and extracurricular activities. The specific stages are as follows:

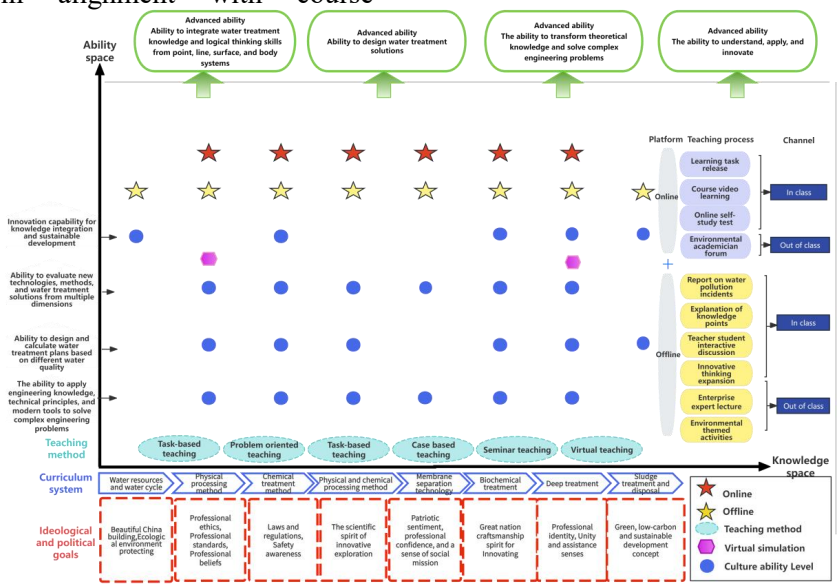


Figure 1. The "2T" Blended Teaching Mode of Water Pollution Control Engineering Course

2.1.1 In-Class online classroom

Four modules are set: learning task release, course video learning, online self-study tests, and teacher-student discussions. Before class, teachers release pre-study tasks online, and students independently study the teaching videos and complete online tests. After class, teachers release discussion topics online, where students research, express opinions, and engage in teacher-student and peer-to-peer

interactions, focusing on cultivating students' autonomous learning and independent thinking abilities through online learning.

2.1.2 In-Class offline classroom

Four modules are set: water pollution event reporting, knowledge point explanation, teacher-student interactive discussion, and innovative thinking expansion training. The water pollution event reporting module involves students, organized into groups, reporting on the latest domestic and international water environment events or new water treatment technologies at the beginning of each class. This encourages students to pay attention to water environment issues, enhancing their communication, expression, and teamwork skills. The knowledge point explanation module helps students understand and master key and difficult points, with ideological and political elements, such as green and low-carbon stories, integrated to foster low-carbon concepts. The teacher-student interactive discussion module involves group discussions to develop students' abilities to analyze and solve complex engineering problems, while the innovative thinking expansion training module encourages students to propose new ideas based on related knowledge points, cultivating innovative thinking.

2.1.3 Extracurricular online module

Expert lectures are regularly organized, allowing students to listen to reports from academicians and experts, enhancing their professional identity and pride and fostering the spirit of craftsmanship.

2.1.4 Extracurricular offline modules

Two modules are set: industry-education classroom and environmental protection-themed activities. In the industry-education classroom, outstanding alumni and industry experts are invited to give lectures, inspiring students to take on the responsibility of serving the country. Environmental protection-themed activities are organized around World Water Day, Earth Day, and World Environment Day, involving both students and faculty. These activities have been held for over a decade and have become a professional hallmark. Through planning, organizing, and participating in these activities, students experience the responsibility and mission of being environmental protection professionals, enhancing their professional identity and sense of social responsibility.

2.2 Deeply Embedding the Low-Carbon Concept and Establishing an "8+8" Course Content System

Cultivating moral character and fostering talent is one of the essential tasks of the course. In this study, the "Water Pollution Control Engineering" course integrates ideological and political elements throughout the eight sections of its teaching content. Based on the key knowledge points taught, the course employs case-based, discussion-based, and problem-oriented approaches to seamlessly incorporate eight types of themes. These themes include the concept of green, low-carbon, and sustainable development; the spirit of scientific innovation and exploration; the craftsmanship spirit of excellence; team collaboration awareness; legal and safety consciousness; patriotism; professional confidence; and a sense of mission to serve the nation, forming an "8+8" teaching content system, as shown in Figure 2, which imparts not only knowledge but also provides students with spiritual guidance on values.

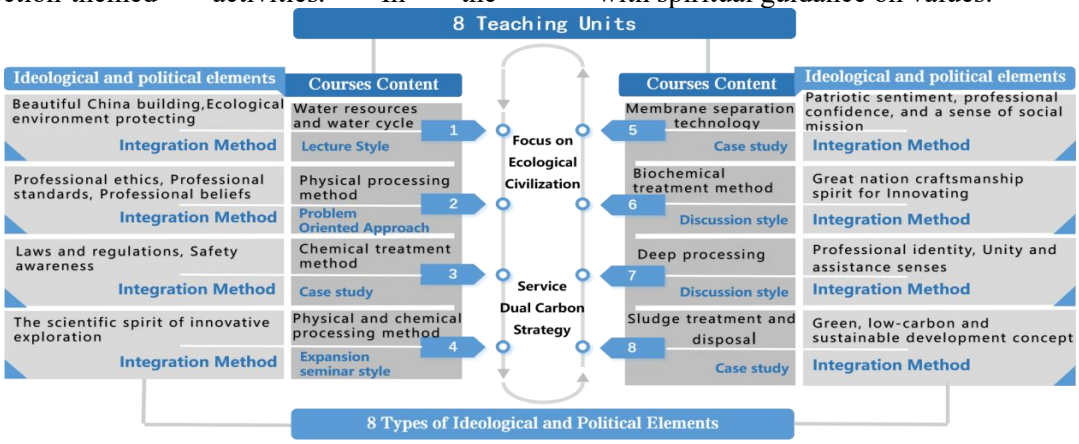
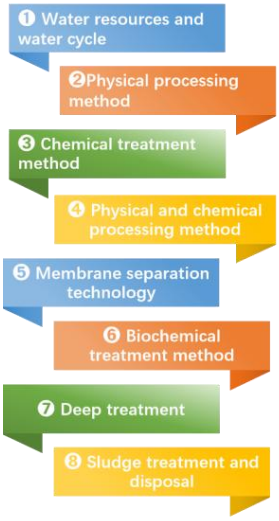


Figure 2. "8+8" Course Content System for Water Pollution Control Engineering

Under the "8+8" teaching content system, a case library has been established based on the knowledge points covered in each part of the course. This library includes over 40 case stories (see Figure 3). For example, when explaining the "biological membrane" method, an example of the use of biological contact oxidation in treating medical wastewater at Leishenshan and Huoshenshan hospitals during the COVID-19 pandemic is introduced. This helps students appreciate the speed, spirit, and strength of China in facing major challenges, and understand that their professional knowledge supports this speed, cultivating a sense of professional identity and patriotism. Similarly, when discussing phosphorus removal processes, the example of phosphorus recovery to produce struvite (bird guano) is introduced, helping students recognize that phosphorus removed from water is not waste but a resource that should be utilized sustainably, thereby fostering a green, low-carbon, and sustainable development concept.



C1 Water resources and water cycle
Case: The road to water control is a long and arduous one. Green mountains and clear waters are mountains of gold and silver

C2 Physical processing method
Case: The earliest grille in China, used for the present, conveying the wisdom of ancient people
Case: Sand settling tank, the "throat" of sewage treatment

C3 Chemical treatment method
Case: Academician Li Guibai: Fighting for Water
Case: Daqing Oilfield Wastewater Treatment Station: Environmental benefits of "eating" dirty oil and "spitting" it out
Case: Implementing laboratory safety regulations is the best responsibility for oneself and others
Case: The bone pain disease incident shows that environmental protection is a sense of responsibility
Case: The issue of environmental safety is a major concern for people's livelihoods

C4 Physical and chemical processing method
Case: 5 years of research and development of KGMB materials, showcasing the innovative and entrepreneurial style of college students
Case: The smoothing of 'scars on the earth' - a new model for mine pollution remediation
Case: Ion exchange technology solves ecological problems in rare earth smelting

C5 Membrane separation technology
Case: The biggest challenge facing electrodialysis technology
Case: The drinking water revolution triggered by a seagull, the trust and favor gained by reverse osmosis technology
Case: New competition track for "ultrafiltration milk"

C6 Biochemical treatment method
Case: Collaborate and division of labor and cooperation of microorganisms in sewage treatment
Case: The past and present of activated sludge process
Case: Development from the perspective of the transformation of aeration methods in water plants
Case: Craftsmanship spirit hones professional level, activated sludge process unleashes new vitality
Case: Professional knowledge is the guarantee of China's speed in the wastewater treatment of Leishenshan and Huoshenshan
Case: Fly ash solid waste turns into environmentally friendly filter material
Case: Rigorously practicing, adhering to norms, ensuring safety and reliability, and promoting industry development
Case: Academician's voice: Serving the people is the greatest achievement of this life
Case: Technology changes and develops, science and technology have no endpoint of exploration

C7 Deep treatment
Case: The wisdom of ancient water treatment is useful for the present
Case: Professor Hao Xiaodi cares about the motherland and promotes the development of anaerobic ammonia oxidation denitrification technology
Case: In terms of service production, breaking through technological bottlenecks, environment is people's livelihood
Case: 'Bird droppings stone' sways into 'diamond'

C8 Sludge treatment and disposal
Case: Remove sludge without staining

Figure 3. Ideological and Political Case Library for Water Pollution Control Engineering Course

2.3 Aligning with Industry Needs and Building Rich and Multi-Dimensional Course Resources to Meet New Talent Cultivation Requirements

To address the new developments and demands in the field of water pollution control, the course knowledge system has been optimized to better align with modern environmental protection industry needs. When developing course resources, two main questions are considered: What type of course resources are needed? And how can these resources assist student learning?

In course development, a demand-oriented approach is adopted, aligning with national green and low-carbon policies and the school's talent cultivation goals. This results in the creation of a "course resource map" which includes various forms of digital course resources such as online shared courses, engineering case libraries, video collections, and course video accounts, meeting the requirements of the Internet+ era and aligning with green and low-carbon water treatment needs.

2.3.1 Online shared courses and resource library

The online shared course for Water Pollution Control Engineering at Heilongjiang University of Science and Technology was launched on the Zhihuishu teaching platform in 2021 and selected for the National Higher Education Smart Education Platform in 2022. The "online" teaching module is different from the "offline" and focuses on student participation and autonomy. The construction of the "online" module includes the determination of platform functions, the optimization and integration of "online" resources, the determination of "online" teaching content, the "online" discussion and teacher-student interaction, the release and inspection and feedback of learning tasks, the

ideological and political development of "online" courses, extracurricular development and the establishment of "online" evaluation system. Over five semesters, 51 institutions have adopted the course, covering 17 provinces, autonomous regions, and municipalities. Since 2022, the course team has conducted live sessions annually on the platform, receiving positive feedback. The course includes 64 online teaching videos, 85 recorded engineering cases, and 200 structure demonstration animations, and it is constantly being updated and supplemented. At the same time, the "Water Pollution Incident Broadcasting" case library module, the "Course Ideology and Politics" section, the "Water Pollution New Technology and Engineering Case Analysis" module, and the "In-class Demonstration Experiment" module were set up, allowing students to learn online anytime and anywhere.

2.3.2 Three-Dimensional virtual simulation system for mine water treatment

As a university with a mining focus, Heilongjiang University of Science and Technology has developed an "Interactive 3D Virtual Simulation System for Mine Water Treatment" to meet the demand for mining talents. Due to safety restrictions in mines, students cannot go underground but can use the virtual simulation system for "scenario-based teaching." This system comprehensively presents the mine water treatment process, from dynamic control settings and real-time operation displays to internal equipment structure demonstrations. It enhances students' understanding of mine water sources and treatment processes, strengthens practical skills, and integrates virtual simulation with real-world engineering practice.

2.3.3 "Shangshan Ruoshui · enlightening wisdom and moistening the heart" course video account

To cater to students' interests and attention, the course team created a video account for the Water Pollution Control Engineering course, named "Shangshan Ruoshui · Enlightening Wisdom and Moistening the Heart." It regularly releases promotional videos for Earth Day, World Water Day, etc., showcasing new technologies, processes, and equipment in wastewater treatment. This approach allows students to conveniently access professional knowledge in their spare time, reinforcing their professional identity and career commitment.

2.3.4 On-site teaching at water treatment internship bases

To address the disconnect between classroom teaching and practical production, the course team actively uses professional internship and industry-academia-research bases, such as sewage treatment plants, for on-site teaching. Teachers conduct live teaching sessions at various sewage treatment plants, which has been well-received by students. This "cloud internship" method has attracted over 3,000 teachers and students from other universities in Harbin to live sessions, and has been covered by mainstream media such as Heilongjiang Daily, Longtou News, Aurora News, and Northeast Net.

2.4 Developing a "4+2" Diversified Evaluation Model to Strengthen Student Competency Assessment

In response to the reform in teaching modes, a "4+2" diversified evaluation model has been developed, consisting of formative assessment (40%) and summative assessment (60%). Formative assessment includes 10% for water pollution event reporting, 5% for problem discussions (online + offline), 15% for assignments (online + offline), and 10% for course reports. Summative assessment includes 36% for closed-book exams and 24% for open-book exams. Water pollution event reporting and problem discussions are assessed as project team evaluations, while other components are individual student assessments, as shown in Figure 4. The "4+2" evaluation model assesses student abilities from multiple dimensions, emphasizes formative assessment, and comprehensively evaluates students' knowledge and problem-solving skills.

3. Impact and Prospects

3.1 Course Survey

To understand student learning outcomes and promote continuous course improvement, a survey is conducted for each cohort of students. The survey results show that 95% of students are satisfied with the course, indicating significant improvements in team collaboration, communication, and problem-solving abilities through activities

like water pollution event reporting, interactive discussions, innovative thinking training, and themed environmental activities.

3.2 Course Education Survey

A survey on the effectiveness of education within the course shows high student recognition of the educational methods and guidance for innovation and entrepreneurship. The recognition rate for the course's education approach is 97%, and over 94.5% of students acknowledge the course's role in fostering patriotism and a sense of mission (see Figure 5).

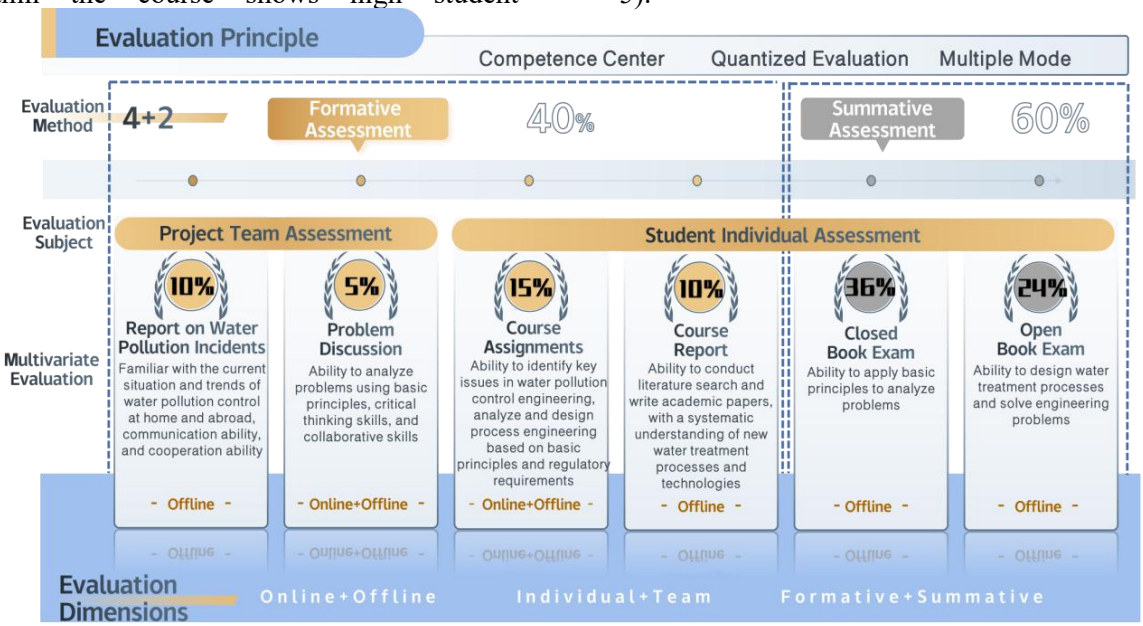


Figure 4. "4+2" Diversified Evaluation Model for Water Pollution Control Engineering

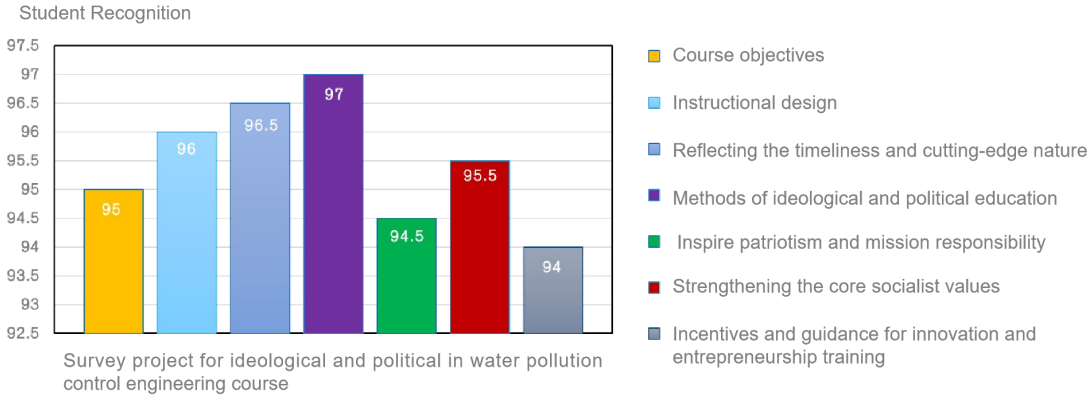


Figure 5. Student Recognition of Education in the Course

3.3 Improvement in Participation and Quality of Innovation and Entrepreneurship Competitions

In recent years, student participation in competitions such as the Internet Innovation and Entrepreneurship Competition and "Low-Carbon Circular Economy" has increased, with notable achievements. The course has won bronze medals in the National "Internet+" College Student Innovation and Entrepreneurship Competition for three consecutive years and has received over 50 awards in provincial and national competitions, including the "Beikong Water Cup" and the inaugural College Student Low-Carbon Circular Economy Competition. This has led to numerous provincial and national-level student research projects, reflecting steady improvements in students' professional identity, industry confidence, research spirit, innovative thinking, and teamwork (see Figure 6).

3.4 Employer Recognition of Graduates

In recent years, the employment rate of graduates in the major has exceeded 94%, with nearly half working in water treatment companies or environmental protection departments. They have received widespread praise from employers for their diligence,

quick adaptability, retention, and applicability.

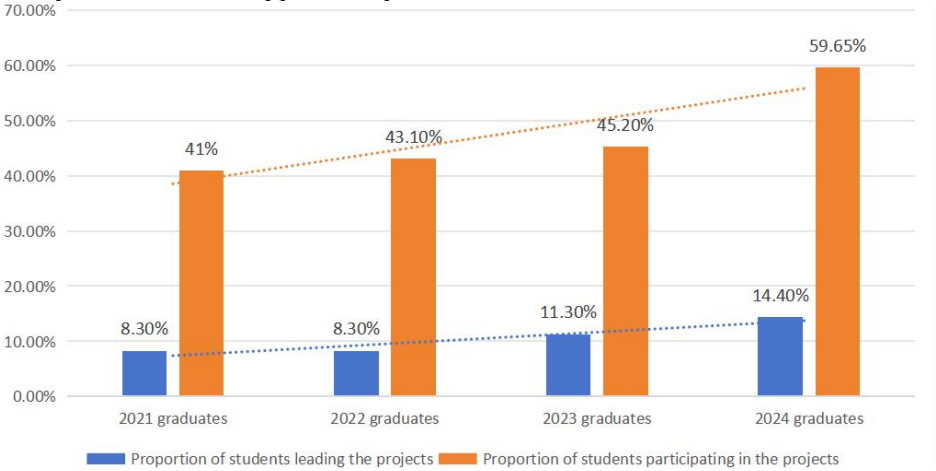


Figure 6. Improvement in Quantity and Quality of Student Participation in Innovation and Entrepreneurship Competitions

4. Future Prospects

In future mixed-mode course system construction and implementation, the Water Pollution Control Engineering course will continue to advance the following teaching reforms and improvements:

4.1 Promote Digital and Integrated Teaching Reform

Following a student-centered approach, regular learning condition surveys will be conducted to further optimize teaching design. By integrating big data, artificial intelligence, and other technologies into course content and extracurricular practices, the teaching design will better align with students' cognitive patterns, enhance learning effectiveness, and expand the reach and impact of online courses.

4.2 Optimize Knowledge System

Continuously update teaching content to address social hot topics and the latest research findings, enhance the knowledge system, and enrich online and offline teaching resources to strengthen student competency development.

4.3 Strengthen Course Team Development

Enhance teacher discussion and exchange, modern teaching skills training, cultivate young teaching talents, build provincial-level teaching teams, and improve team teaching standards.

Acknowledgments

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