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Curriculum Reform of "Solid Waste Treatment and Utilization" Based on OBE Teaching Concept

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Abstract: To achieve the goal of comprehensive green transformation of economic and social development proposed in the suggestions for the 15th Five-Year Plan, against the background of the integration of Emerging-Engineering construction and ecological-civilization development, *Solid Waste Treatment and Utilization* is a core course for the higher-vocational major of Environmental Engineering Technology. Its traditional teaching mode suffers from problems including disconnection between theory and practice, outdated content, and simplistic evaluation. Centering on the concept of Outcome-Based Education (OBE), this paper designs curriculum-reform paths from five dimensions: modular reconstruction of teaching contents, digital construction of teaching resources, diversification-oriented innovation of teaching modes, subtle integration of curriculum-based ideological-and-political education, and multi-dimensional construction of teaching evaluation. By developing virtual-simulation training platforms, compiling loose-leaf textbooks, deepening industry-education integration, and promoting teaching through competitions, it effectively improves students' core skills in solid-waste treatment and environmental-protection literacy, realizes the talent-cultivation goal of fostering virtue through education, and provides references for curriculum reform of the higher-vocational Environmental Engineering Technology major.

Keywords: OBE teaching concept; Solid waste treatment and utilization; Environmental engineering technology; Curriculum reform; Industry-education integration

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1. Introduction

With the advancement of national strategies such as the carbon-peak and carbon-neutrality goals [1] and zero-waste-city construction [2], the contradiction between the continuous growth of solid-waste output in China and the demand for resource utilization has become increasingly prominent. The environmental-protection industry is in urgent need of front-line technical talents with core solid-waste-treatment skills. As an important major for cultivating applied talents in the environmental-protection field, the higher-vocational Environmental Engineering Technology major offers the core course *Solid Waste Treatment and Utilization*. This course directly determines students' mastery of solid-waste technologies of "reduction, harmless treatment and resource utilization" [3], as well as their adaptability to industrial posts.

Traditional courses have gradually shown certain teaching limitations in long-term teaching practice. First, teaching contents are outdated. Existing contents provide insufficient coverage of emerging technologies such as pyrolysis and gasification [4], collaborative disposal [5], as well as zero-waste-city cases, and laws, regulations, and standards fail to keep up to date. Second, the practical-teaching system lacks sufficient support. Restricted by safety and environmental-protection requirements of solid-waste-treatment facilities, students can hardly carry out hands-on practice drills and are deficient in capabilities to solve practical problems. Third, teaching modes are relatively single and rigid. Course teaching mostly adopts the traditional teacher-dominated indoctrination-oriented lecturing mode. Students mostly receive knowledge passively. Interactive teaching sessions in class are insufficient, which cannot effectively stimulate students' exploratory thinking and research interest in complex engineering problems. Fourth, the curriculum-assessment-and-eval uation system is not comprehensive enough. The existing assessment mode centers on closed-book theoretical final-term examinations, focusing on memorization and mastery of professional theoretical knowledge, while insufficient weight is given to assessment of students' practical-operation abilities, innovative thinking, engineering-application capabilities and other core qualities. Fifth, the integration of curriculum-based ideological-and-political education lacks depth. Ideological-and-political elements are incorporated in a superficial manner in traditional teaching, without in-depth combination of ecological-civilization concepts, engineering ethics and professional knowledge [6].

Outcome-Based Education (OBE) is an internationally-recognized advanced educational concept. Its core is to take students' learning outcomes as objectives, design curriculum systems and teaching sessions in reverse, and stress student-centered education, outcome orientation and continuous improvement [7]. Introducing the OBE concept into the curriculum reform of *Solid Waste Treatment and Utilization* enables teachers to reconstruct teaching content, innovate teaching methods, and optimize evaluation systems in reverse by clarifying knowledge, ability, and literacy outcomes that students are expected to possess upon graduation. It realizes the transformation from "what to teach" to "what students can learn", and ultimately cultivates compound talents who "master technologies, can do practice and are good at innovation" to meet the demands of the environmental-protection industry in the era of new-quality productive forces.

2. Significance of curriculum reform

2.1. Meeting national-strategy and industrial-development demands

The suggestions for China's 15th Five-Year Plan clearly propose to improve the system for total-resource management and comprehensive conservation, raise the level of garbage classification and resource utilization, and boost the development of circular economy. Efforts shall be continuously made to build national ecological-civilization pilot zones, pioneer zones for Beautiful-China construction and high-grounds for green-development [8]. The curriculum reform of *Solid Waste Treatment and Utilization* enables students to master urgently-needed industrial technologies such as pyrolysis-gasification and waste-battery recycling, understand strategic connotations including circular economy and ecological civilization, satisfy enterprises' talent demands for technical upgrading, and facilitate the realization of carbon-peak and carbon-neutrality goals.

2.2. Supporting talent-cultivation objectives of the environmental engineering technology major

The talent-cultivation objective of the higher-vocational Environmental Engineering Technology major is

to cultivate highly-skilled talents who can engage in environmental monitoring, environmental remediation, solid-waste treatment, and other work. Through teaching-mode innovation, students can master skills including solid-waste classification, treatment-and-disposal technologies and engineering-project design. Virtual-simulation platforms help avoid safety risks and improve students' operational proficiency. Industry-education integration connects real-world industrial demands and shortens students' post-adaptation period.

2.3. Enhancing students' employment competitiveness and career-development potential

Current posts in environmental-protection enterprises require both practical experience in solid-waste treatment and professional-skill certificates. The OBE-oriented mode enables students to possess dual advantages of certificates and project experience upon employment. Meanwhile, competition-driven and project-based teaching can cultivate students' innovative thinking and provide driving forces for their subsequent career development.

3. Design of curriculum-reform paths based on OBE teaching concept

3.1. Modular reconstruction of teaching contents: Aligning with learning-outcome objectives

Centering on knowledge, ability and literacy that students are expected to possess upon graduation, teaching contents of *Solid Waste Treatment and Utilization* are layered as basics--technologies--application--innovation, forming 4 major modules and 12 sub-modules (**Figure 1**).



Figure 1. Modular Course Contents of Solid Waste Treatment and Utilization.

3.2. Digital construction of teaching resources: Breaking bottlenecks in practical teaching

3.2.1. Compilation of dynamic loose-leaf textbooks

Jointly with on-campus dual-qualified teachers and enterprise technical experts, compile loose-leaf textbooks containing up-to-date theoretical knowledge, technical methods, laws and regulations. Thus, contents of new technologies such as pyrolysis-gasification and waste-battery recycling keep pace with industrial development, and students can learn the *Eco-Environmental Code of the People's Republic of China*, the latest eco-environmental law [9].

3.2.2. Development of virtual-simulation training platform

Cooperate with virtual-simulation-technology companies to develop a platform where students can operate via computers or VR devices without real-world safety risks. The platform records operation steps and results, and teachers can view real-time data and offer guidance and corrections.

3.2.3. Integration of high-quality online resources

Integrate online teaching resources on the Fanya Course Platform. Introduce the national high-quality open-online course *Solid Waste Disposal and Resource Utilization* presented by Ma Junwei from Beijing Normal University for students' preview and review before and after class. Collect on-site shooting videos of solid-waste-treatment workshops in environmental-protection enterprises to familiarize students with real-world production environments. The research team compiles an online question bank for automatic marking on the platform, allowing students to do supplementary exercises targeting weak knowledge points [10].

3.3. Diversified innovation of teaching modes: Stimulating students' active learning

3.3.1. Combination of case-based teaching and task-driven teaching

Each chapter starts with real-world industrial cases and sets driving tasks. Students work in groups to consult documents, conduct discussion and analysis, formulate rectification plans and make class presentations. Teachers offer comments and summaries to guide students to master core technologies.

3.3.2. Project-based teaching integrated with multiple evaluations

Set solid-waste-treatment-engineering-design projects in the comprehensive-application-and-innovation module. Students are required to complete engineering-design schemes in groups, and enterprise engineers are invited to participate in reviews and put forward revision suggestions. Project-based teaching integrates knowledge points and improves students' capabilities in engineering design and teamwork.

3.3.4. Deepening practical teaching via industry-education integration

Sign school-enterprise cooperation agreements with leading environmental-protection enterprises in Suzhou and build off-campus training bases. Arrange for students to take cognitive internships every semester, participate in real-world post-work under the joint guidance of enterprise mentors and on-campus teachers, and finish internship reports. Meanwhile, invite enterprise technical experts to give lectures on campus, explaining practical technical difficulties and industrial-development trends so as to improve students' capabilities to solve real-world problems.

3.3.5. Chemical inspector certificate and competition-driven mechanism

Integrate assessment contents of the Intermediate-Level Chemical Inspector Vocational-Skill-Level Certificate into courses. Skills required by the certificate, including tool-and-equipment operation, sample collection, processing and pre-treatment, and physical-and-chemical-property testing of samples, are incorporated into teaching and training of basic modules and treatment-technology modules. Organize students to take certificate examinations upon course completion, and the pass rate is included in curriculum-effect evaluation. Meanwhile, guide students to participate in competitions such as the "Internet-plus" Innovation Competition and the "Challenge Cup" Skill Competition. Competition achievements are counted in course evaluation with extra points to stimulate enthusiasm for innovation.

3.4. Subtle integration of curriculum-based ideological-and-political education: implementing the fundamental task of fostering virtue through education

3.4.1. Systematic exploration of ideological-and-political elements

Sort out ideological-and-political elements according to the teaching modules of *Solid Waste Treatment and*

Utilization, and form a list of ideological-and-political elements for the solid-waste-treatment course (**Table 1**).

Table 1. List of Ideological-and-Political Elements for the Solid-Waste-Treatment Course

Module Type	Ideological-and-Political Element	Integration Carrier	Value Objective
Basic Theory	Awareness of the rule of law	Evolution of the *Solid Waste Law* (from end-of-pipe governance to source reduction)	Cultivate students' consciousness of abiding by environmental-protection laws and regulations
Core Treatment Technology	Serving the country through science and technology	Independent-R&D history of domestic waste-incineration furnaces (from imported to domestic-made)	Enhance national pride and confidence in science and technology
Core Treatment Technology	Devotion to home and country	Cases of daily clearance of medical solid waste during the COVID-19 pandemic	Learn the dedication spirit of environmental-protection practitioners
Solid-Waste Resource Utilization	Ecological civilization	Achievements of zero-waste-city pilot construction (e.g. Shenzhen, Suzhou)	Practice the concept of "Lucid waters and lush mountains are invaluable assets"
Solid-Waste Resource Utilization	Spirit of innovation	Waste-battery-recycling-technology development from crude dismantling to green recycling	Inspire students' sense of responsibility for technological innovation
Comprehensive Application and Innovation	Engineering ethics	Cases for coping with NIMBY (Not-In-My-Backyard) effect of waste-incineration plants	Cultivate public-communication capabilities and sense of social responsibility

3.4.2. Diversified ways for ideological-and-political integration

The course *Solid Waste Treatment and Utilization* realizes organic integration of ideological-and-political elements from four dimensions: classroom lecturing, case seminars, practical teaching and second-classroom activities. For instance, in teaching composting-technology-related knowledge points, extend lectures by combining the ecological wisdom of straw returning to fields in traditional Chinese agriculture, and guide students to establish professional concepts of green development and cyclic utilization. Set typical teaching topics concerning engineering ethics. Take real-world industrial scenarios of illegal transfer and disposal of hazardous waste by environmental-protection enterprises as entry points, and guide students to discuss professional bottom-lines and social-responsibility commitment of environmental-protection technicians so as to cultivate their professional ethics and awareness of the rule of law. Build real-emergency-disposal scenarios on the professional virtual-simulation teaching platform, and set training modules for reporting procedures and standardized-disposal methods upon discovering illegal solid-waste dumping, extending in-class ideological-and-political education to off-campus practical scenarios. Regularly carry out second-classroom activities such as ecological-environmental-protection public-welfare lectures, and encourage students to enter communities for garbage-classification knowledge popularization and environmental-protection publicity services, so as to temper professional capabilities and strengthen their sense of social responsibility and dedication in social practice and public-welfare services.

3.4.3. Support for ideological-and-political teaching resources

Build a compound ideological-and-political teaching team of "professional teachers + ideological-and-political teachers + enterprise mentors". Leverage the advantages of multi-subject collaborative education to jointly develop and systematically construct curriculum-based ideological-and-political teaching resources. Build a standardized case bank for curriculum-based ideological-and-political education to guarantee completeness

and practicality of case teaching. Develop high-quality micro-lecture resources for curriculum-based ideological-and-political education, and create theme micro-lectures such as *From "Garbage-Surrounded Cities" to Zero-Waste Cities* starting from industrial development and social hot-spots, adapting to fragmented and lightweight modern-teaching scenarios. Compile practical-guidance handbooks for curriculum-based ideological-and-political education, focusing on practical-education links such as students' professional internships and discipline competitions, so as to realize effective connection between theoretical ideological-and-political education and practical ideological-and-political cultivation.

3.5. Multi-dimensional construction of teaching evaluation: Guaranteeing outcome achievement and continuous improvement

Break the traditional single-evaluation mode, and build an evaluation-system integrating process-oriented evaluation, summative evaluation and multi-subject evaluation, focusing on the achievement and continuous improvement of students' learning outcomes. Meanwhile, establish a closed-loop mechanism of "evaluation --feedback--improvement": (1) Regular feedback: collect opinions via questionnaires and symposiums at the end of each semester; (2) Outcome analysis: compare evaluation data and identify weak links; (3) Continuous improvement: adjust courses and track effects in the next semester to ensure sustained improvement of course quality.

4. Practical effects of curriculum reform

Driven by the OBE teaching concept, more suitable teaching methods, teaching designs, course standards and teaching plans have been formed. Students' course pass rate has risen from 85 % before reform to 97 %, and the excellence rate (scores above 90 points) has increased from 20 % to 35 %. The pass rate for the Chemical Inspector Vocational-Skill-Level Certificate has gone up from 60 % to 90 %. Students have won 1 first-prize award in provincial-or-above innovation-and-entrepreneurship competitions and obtained 2 relevant patents. The employment rate of graduates in environmental-protection enterprises has increased by 15 % after reform. The proportion of enterprises reporting that graduates possess strong practical capabilities and can quickly adapt to post requirements has risen from 65 % to 90 %, winning consistent praise from enterprises.

5. Conclusion and outlook

The curriculum reform of *Solid Waste Treatment and Utilization* based on the OBE concept effectively addresses pain points in traditional teaching through modularized teaching contents, digitalized resources, diversified modes, subtle ideological-and-political integration and multi-dimensional evaluation. It achieves three-dimensional learning outcomes of knowledge, ability, and literacy, and cultivates applied talents meeting the demands of the environmental-protection industry. Nevertheless, deficiencies still exist in the reform. First, the coverage of virtual-simulation resources is limited. Second, the depth of school-enterprise cooperation needs to be enhanced.

In future curriculum reform, virtual-simulation resources will be further expanded by adding scenarios for agricultural solid-waste treatment and construction-waste disposal. Industry-education integration will be deepened by jointly building a green-technology industrial college with environmental-protection enterprises and carrying out order-oriented talent cultivation. Keep track of industrial-technology development, timely

incorporate new technologies such as solid-waste pyrolysis-gasification and AI monitoring into courses, and continuously optimize the "evaluation--feedback--improvement" mechanism, so as to cultivate more en vironmentally-engineering-technology talents with both professional competence and moral integrity for ecological-civilization construction.

Disclosure statement

The authors declare no conflict of interest.

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