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RESEARCH ARTICLE

A Preliminary Study on the Teaching Reform of Course Case Database

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Abstract

To address the core challenges identified in the course "New Technologies in Water Technology and Engineering"—specifically, the abstract nature of theoretical knowledge, limited relevance of existing case studies, and inadequate development of practical competencies—a customized teaching case library was developed. This initiative followed a structured four-stage methodology: knowledge decomposition, case selection, adaptive design, and solution coordination. Encompassing eight major emerging technology domains, the case library was constructed under three guiding principles: strict alignment with curricular objectives, sustained technological focus, and progressive skill advancement. Its architecture integrates four cohesive modules (technical background→process design→ problem-solving→extended thinking), ensuring comprehensive coverage of core curricular components. Implementation of the case library in teaching yielded substantial improvements: classroom interaction rates increased from 57% to 88%, while satisfaction rates regarding the clarity of new technology principles, course practicality, and teaching innovation rose to 92%, 94%, and 91%, respectively. The average score on final comprehensive design questions improved from 77 to 83.5, and the pass rate for engineering application questions concerning new technologies increased from 68% to 89%. This case library, along with its associated pedagogical reform framework, effectively bridges the gap between theoretical instruction and practical application. It provides a replicable model for similar emerging technology courses and exemplifies the advancement of industry–education integration in engineering education.

Keywords: case-based teaching, engineering practice-oriented, teaching reform, application of new technologies.

1 Introduction

In the context of evolving environmental pollution and rapid advancements in water treatment technologies in China, there is an increasing need to innovate and reform both the content and teaching methods of undergraduate education [1]. As a fundamental component of the water supply and drainage science and engineering curriculum, the course "New Technologies in Water Technology and Engineering" plays a crucial role in introducing cutting-edge water treatment methods and enhancing engineering

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practical skills. The effectiveness of instruction in this course significantly impacts students' ability to understand and apply emerging technologies—such as ozone-biological activated carbon (O_3-BAC) and membrane separation.

However, current teaching approaches face two major challenges. First, the abstract principles behind new technologies make them difficult to grasp. Core mechanisms—like those involved in reverse osmosis membrane separation and anaerobic ammonium oxidation—are often taught only through theoretical formulas and process diagrams without reference to real engineering contexts. Important practical considerations, such as the impact of raw water quality variations on treatment efficiency and the operational parameters of critical equipment, are frequently overlooked. As a result, students find it hard to connect theoretical knowledge with technological implementation and real-world application.

Second, case-based instruction often lacks flexibility and depth. Existing case studies tend to be oversimplified, drawn either from fragmented research papers or generalized engineering examples that do not adequately reflect the unique characteristics of specific new technologies. Moreover, the accompanying teaching plans are often underdeveloped, failing to effectively bridge theoretical concepts with practical engineering requirements [2].

Case library instruction is an effective strategy for bridging theory and practice in higher education [3–5]. It has been shown to enhance students' engineering competencies. While this approach has been successfully implemented in courses such as Water Treatment Engineering [6–8], a dedicated case library tailored for the course "New Technologies in Water Technology and Engineering" remains underdeveloped. Most existing case libraries within the water supply and drainage discipline focus predominantly on conventional processes, with a conspicuous scarcity of cases addressing new technologies. Moreover, those case libraries that do incorporate new technologies often emphasize research-oriented depth, which may not align with the pedagogical objectives of undergraduate education. To address these gaps, this study develops a practice-oriented case library specifically designed for the course "New Technologies in Water Technology and Engineering". It systematically elaborates on the theoretical foundation, development methodology, integration strategies, and reform outcomes associated with the case library implementation. The results offer valuable insights for the advancement of pedagogical reforms in similar emerging technology courses.

2 Construction of a Case Library for the Course "New Technologies in Water Technology and Engineering"

The case library is constructed with the core objectives of aligning with curricular knowledge units, addressing the demands of new technological engineering applications, and supporting instructional goals. Its development process comprises four stages: decomposition of course knowledge points, selection of new technology cases, adaptation and design for course integration, and coordination with teaching plans. Ultimately, eight representative cases were formed, comprehensively covering all core new technology modules within the course.

2.1 Construction Principles: Dual Objectives of Anchoring Course Instruction and New Technology Application

The case library construction shifts away from the conventional emphasis on theory over practice by establishing three core principles deeply integrated throughout the development process. First, the curricular adaptability principle requires that all cases strictly correspond to course knowledge units. For instance, the "O_3-BAC Advanced Treatment" case aligns specifically with the chapter on "Advanced Drinking Water Treatment Technology," emphasizing key curricular content such as the relationship between ozone dosage and chemical oxygen demand (COD), as well as the regulation of activated carbon biofilm. This ensures that the cases resonate with students' knowledge structures. Second, the new technology focus principle guides the selection of case materials around the course's core emphasis on emerging technologies. The library comprehensively covers pivotal technologies including ozone oxidation, membrane separation, anaerobic enhancement, and ecological treatment. For example, the "Ultrafiltration–Reverse Osmosis Coupled Seawater Desalination" case focuses on essential course topics such as the engineering parameter design and operational aspects of membrane separation technologies. Finally, the capability progression principle organizes cases along a gradient that mirrors the course's instructional sequence. It begins with fundamental application cases, such as "Anaerobic–Anoxic–Oxic Activated Sludge Process

(AAO) Enhancement (upgraded conventional technology)," progresses to systematic design cases like "O_3-BAC Advanced Treatment (mature new technology)," and advances to complex scenario-based cases such as "Phenol Leakage Emergency Treatment (emergency application of new technology)." This structure aligns with students' cognitive progression in mastering new technologies—from comprehension and application to innovation.

2.2 Case Structure: Constructing a Dual-Driven Framework of "Course Knowledge Points and Engineering Practice"

Each case is designed around a dual-core approach that integrates knowledge point decomposition with engineering application, forming a progressive structure composed of four modules: technical background, process design, problem solving, and extended thinking. These four interconnected modules support the concurrent development of knowledge and practical skills.

The technical background module is closely aligned with real-world technological application scenarios addressed in the course. It introduces key concepts by anchoring them in genuine engineering needs. For example, the case "Reclaimed Water Reuse in Arid Western Cities" draws upon the realistic context of addressing water scarcity and sewage discharge challenges to introduce the core concept of Reclaimed Water reuse Treatment Technology, thereby enabling students to intuitively comprehend the practical relevance of new technological knowledge.

The process design module emphasizes the integration of technological principles with engineering parameters, preventing a disconnect between theoretical instruction and practical design. Taking the "O_3-BAC Advanced Treatment" case as an example, it moves beyond schematic diagram presentation to incorporate empirical data—such as COD removal rates of 58% at an ozone dosage of 1.2 mg/L and 72% at 1.8 mg/L—guiding students to deconstruct the principles of ozone oxidation reaction kinetics. This method aids students in understanding quantitative dose-effect relationships and mastering the optimization logic of ozone dosing in engineering contexts.

The problem-solving module focuses on challenges in the operation of new technologies. By illustrating actual operational issues and their resolution procedures, it enhances students' engineering practical skills. For instance, in membrane treatment cases, the module elaborates a systematic troubleshooting process: "monitoring membrane fouling → analyzing contamination causes → selecting chemical cleaning agents and controlling concentration," thereby cultivating students' ability to transition from parameter anomaly identification to technical problem resolution.

The extended thinking module is positioned at the forefront of emerging technologies within the course. Building on practical case training, it encourages students to explore technological optimization and future trends. Using the "seawater desalination" case as an example, it prompts discussion on topics such as "the impact of low-energy membrane material development on operational costs" and "engineering approaches for concentrated brine resource utilization," thereby bridging cutting-edge advancements with innovative thinking.

Across the four modules, the logical sequence of "demand introduction → principle implementation → operational practice → frontier exploration" enables the curriculum to achieve a layered and organic integration of theoretical knowledge and engineering practice capabilities.

2.3 Case Coverage: Achieving Comprehensive Coverage of Core New Technology Modules in the Curriculum

The case library covers all eight core chapters of the course, following a "one chapter, one case; one technology, one practice" structure (Table 1). The case selections are designed to achieve a balance between the "application of mature emerging technologies" and the "exploration of cutting-edge new technologies."

3 Teaching Reform Path for Integrating Case Library into the Course "New Technologies in Water Technology and Engineering"

3.1 Precise Section Alignment: Deep Integration of Case Studies with Course Knowledge Points

A three-dimensional framework of "chapter knowledge points–case modules–competency objectives" is established to achieve seamless integration between case studies and course content. For instance:

- In the chapter "New Biological Treatment Technologies," the case "AAO Process for Enhanced Nitrogen and Phosphorus Removal" is introduced. Through the logical progression of "bottleneck in TN removal

Table 1. Core cases in the developed case library.

Core Course Modules	Case Name	Focus on New Technology Knowledge Points in the Course	Core Competency Development
Advanced Treatment Technology for Drinking Water	O_3-BAC advanced treatment	Synergistic effect of ozone oxidation,activated carbon adsorption and biological degradation	Selection of process and optimization of parameters for deep processing technology
	Pre-oxidation + dissolved air flotation	Principle of preoxidation for algae destruction and design of technical parameters for air floating separation	Application ability of new technology for water pollution control
Advanced Technology of Sewage Treatment	AAO process for enhanced nitrogen and phosphorus removal	Principle of enhanced biological nitrogen and phosphorus removal and carbon source regulation technology	Upgrade of traditional technology and application ability of new technology
	UASB+ contact oxidation for food wastewater treatment	New technology of anaerobic biological treatment and principle of aerobic biological contact oxidation	Design capability of new technology for high concentration wastewater treatment
Reclaimed Water Reuse Treatment Technology	Separation and treatment of municipal and industrial reuse	Principle of Reclaimed Water reuse Treatment and Matching Technology of Reclaimed Water Quality	Design and application of new technology process for reclaimed water
New Technology of Emergency Water Treatment	Emergency treatment of phenol leakage	Emergency Oxidation-Adsorption Synergistic Technology and optimization of chemical addition	New technology disposal capability for sudden pollution emergency
Distributed Water Treatment Technology	Biological contact oxidation+constructed wetland in village	Distributed biological treatment technology and new ecological treatment technologies	Low-cost decentralized processing technology design capability
New Membrane Separation Technology	Ultrafiltration-reverse osmosis coupled seawater desalination	Ultrafiltration, reverse osmosis membrane separation principle, membrane pollution prevention technology	System design and operation and maintenance capability of new membrane separation technology

rate in the original process → application of enhancement technologies such as carbon source supplementation and reflux ratio adjustment→effectiveness after modification," core knowledge points including "principles of enhanced biological nitrogen and phosphorus removal" and "C/N ratio control technology" are elucidated.

- In the chapter "New Membrane Separation Technologies," cases such as "Ultrafiltration Treatment of Reclaimed Water" and "Reverse Osmosis for Seawater Desalination" are incorporated. Using the instructional logic of "comparing membrane fouling characteristics across different water qualities (reclaimed water vs. seawater)→differentiating pollution prevention technologies," the knowledge point of "membrane fouling mechanisms and prevention strategies" is reinforced.

- In the chapter "Emergency Water Treatment Technology," the case "Phenol Leakage Emergency Response" serves as a central example to conduct full-process teaching covering "pollution monitoring→selection of oxidation and adsorption technologies→dosage calculation," thereby encompassing the knowledge point of "synergistic effects of emerging emergency treatment technologies."

3.2 Teaching Method Innovation: Constructing a Three-Step Model of "Case Introduction-Principle Decomposition-Engineering Practice"

Breaking away from the traditional "principle instruction + case supplementation" model, we have proposed a dynamic three-stage interactive teaching method tailored specifically for new technology courses, which effectively integrates case studies with theoretical principles and hands-on practice. The first stage employs case-based introduction, igniting students' curiosity through practical engineering challenges. For instance, teaching "Ozone Oxidation Technology" begins by unfolding an engineering video, "Northern Reservoir Water Plant Shutdown Due to Excessive Organic Matter," vividly illustrating the technology's critical need. This seamlessly transitions into the "O_3-BAC Advanced Treatment" case study, posing the pivotal question: "How can ozone oxidation effectively reduce organic matter concentration?" to forge a direct link with core course concepts. The second stage focuses on principle decomposition, using authentic case data to visualize abstract theories. Taking ozone oxidation kinetics as an example, we visually demonstrate measured results like "60% COD removal at 1.5mg/L ozone dosage and 70% at 2.0mg/L," enabling students to independently derive reaction kinetics equations. This achieves the crucial cognitive leap from raw "data" to fundamental "principles." The third stage emphasizes engineering practice, challenging students with practical tasks rooted in case scenarios. Following the "Seawater Desalination" case, we assign the task: "Designing a Membrane System for a Coastal Seawater Desalination Project." Students must synthesize course principles and case-specific parameter design experience to complete the entire process—including membrane selection, operating pressure optimization, and scale inhibitor dosage calculation—before submitting comprehensive proposals. In addition, we establish a dedicated "Case Study Platform." Each chapter poses targeted optimization challenges in new technology applications, such as "How to minimize ozone consumption in O_3-BAC processes?" or "How to enhance ecological treatment stability for rural sewage?" Through post-class reflection and vigorous discussion, we cultivate essential new technological optimization thinking and critical thinking skills.

4 Effect of the Teaching Reform on the Course "New Technologies in Water Technology and Engineering"

The teaching reform centered on case library integration optimization and the innovative "case introduction-principle decomposition-engineering practice" teaching model has achieved remarkable breakthroughs in student engagement, satisfaction, and assessment outcomes. In terms of participation, the authentic engineering scenarios and rich details within the course-specific case library powerfully stimulated students' intrinsic motivation. Classroom interaction rates surged from 57% to 88%, while average speaking frequency in "New Technology Optimization" discussions climbed from 0.9 to 2.6 instances per session. The proportion of students independently consulting engineering specifications and technical manuals soared from 25% to 66%, marking a complete transformation from passive learning patterns. Regarding satisfaction, anonymous course evaluations revealed that post-reform student satisfaction with "new technology principle comprehensibility," "course practicality," and "teaching method innovation" reached impressive highs of 92%, 94%, and 91% respectively—significantly higher than the pre-reform figures of 75%, 78% and 72%—demonstrating a substantially enhanced learning experience. In assessment results, the average score for final comprehensive design questions rose from 77 to 83.5, the pass rate for new technology engineering application questions jumped from 68% to 89%, the excellent assessment rate ($\geq$90 points) improved from 10.2% to 15.6%, and theoretical-case matching accuracy increased from 80.9% to 93.7%. These comprehensive indicators vividly demonstrate the teaching reform's strong impact in strengthening students' knowledge mastery and capability development, effectively tackling the core pain point of "theoretical-practical disconnection" within the course.

5 Reflection and Prospect of Teaching Reform of the Course "New Technologies in Water Technology and Engineering"

The case library teaching reform has effectively tackled the core challenge of "theoretical-practical disconnection" in the course "New Technologies in Water Technology and Engineering". However, given the rapidly evolving nature of new technologies in this field, several critical areas demand improvement. Firstly, the dynamic update mechanism for the case library requires significant refinement. Current cases predominantly focus on mature technological achievements from the 13th Five-Year Plan period, yet lack sufficient coverage of emerging technologies during the 14th Five-Year Plan. Cases in cutting-edge fields like "low-carbon water treatment technology (anaerobic ammonium oxidation)" and "smart membrane system operation and maintenance technology" are notably absent, failing to fully meet the frontier demands of new technology education. Additionally, university-enterprise collaboration lacks depth. Current case updates rely mainly on teachers' engineering practical experience, with insufficient participation from corporate technical experts. This results in discrepancies between certain case details and the latest industry operation standards, making it difficult to accurately align with enterprises' actual needs for new technology application capabilities.

Future curriculum reforms can be effectively advanced through multiple dimensions to establish a comprehensive optimization pathway of "case updates-carrier upgrades-integrated teaching". First, a robust, long-term "school-enterprise collaboration" mechanism for case updates must be established. This involves joint case development workshops with water utilities and municipal design institutes, where technical experts provide the latest engineering case materials and precise technical parameters. Course instructors are then responsible for carefully adapting case knowledge points and transforming them into compelling teaching materials, while simultaneously producing on-site teaching videos to ensure the case library's timeliness and authenticity. Furthermore, a dedicated virtual simulation teaching platform for "New Technologies in Water Technology and Engineering" should be developed. Focusing on core course knowledge points, practical modules such as "Membrane Contamination Control", "Ozone Oxidation System Commissioning", and "Anaerobic Reactor Startup" should be created. By leveraging VR technology to meticulously reconstruct intricate equipment internal structures and dynamic operational scenarios, students can gain hands-on experience in virtual environments, significantly enhancing their engineering practice capabilities.

6 Conclusion

Centered on an engineering practice orientation, this study constructed a specialized case library for the course "New Technologies in Water Technology and Engineering." Through a comprehensive three-dimensional teaching reform approach—featuring chapter precision alignment, innovative teaching methodologies, and optimized evaluation systems—it effectively tackled the course's core challenges of "abstract new technology principles and weak engineering applications." Teaching practice demonstrated that this model significantly enhanced students' new technology application skills and course satisfaction, concurrently elevating overall teaching quality. The case library's teaching reform provides a complete, demonstrable pathway encompassing "case construction, teaching integration, and effectiveness assurance" for "New Technologies in Water Technology and Engineering" and similar new technology courses. This initiative holds significant demonstrative value for advancing "industry-education integration and science-education convergence" within higher engineering new technology education.

Data Availability Statement

Data will be made available on request.

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Conflicts of Interest

The authors declare no conflicts of interest.

AI Use Statement

The authors declare that no generative AI was used in the preparation of this manuscript.

Ethical Approval and Consent to Participate

Not applicable.

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