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Reform and Practice of Case-Based Teaching in the Course of Environmental Reaction Engineering

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Abstract: Environmental Reaction Engineering is a core environmental engineering course with strong theoretical and interdisciplinary characteristics. Traditional teaching methods often emphasize theoretical derivation while neglecting practical engineering applications, limiting students' engineering thinking and problem-solving abilities. To address this issue, a progressive case-based teaching framework was developed, covering "pollution problem–reaction mechanism–kinetic analysis–reactor design–engineering optimization." Representative engineering cases, such as SCR denitrification, SO_2 catalytic conversion, and heterogeneous catalytic reactions, were integrated into classroom teaching to connect theory with practice. The course also incorporated MATLAB simulation, problem-based learning (PBL), group discussion, and Outcome-Based Education (OBE) concepts to enhance student engagement and learning effectiveness. Teaching practice showed that this approach improved students' understanding of complex reaction systems, strengthened their engineering analysis and practical problem-solving skills, and increased classroom participation and learning motivation. Overall, the proposed teaching model provides an effective strategy for improving Environmental Reaction Engineering education and offers valuable insights for curriculum reform in environmental engineering and related disciplines.

1. Introduction

With the rapid development of industrialization and urbanization, environmental pollution problems such as air pollution, water contamination, and solid waste accumulation have become increasingly severe worldwide. Environmental engineering programs are therefore expected to cultivate engineering professionals capable of pollution control, resource utilization, and sustainable environmental management. Among the professional core courses, Environmental Reaction Engineering plays an essential role in developing students' abilities to analyze and solve complex environmental engineering problems.

Environmental Reaction Engineering is developed on the basis of chemical reaction engineering and focuses on the migration, transformation, and control of pollutants in environmental systems. The course involves reaction kinetics, thermodynamics, reactor design, heat transfer, and mass transfer processes, requiring students to comprehensively understand the coupling relationships among transport phenomena and chemical reactions[1–3]. However, traditional teaching approaches for this course still exhibit several limitations. First, excessive attention is often paid to mathematical derivations and theoretical equations, while practical engineering applications are relatively neglected. As a result, many students are capable of solving equations mechanically but lack the ability to analyze real engineering problems. Second, students majoring in environmental engineering generally possess weaker chemical engineering foundations, especially in the understanding of transport phenomena and reaction engineering theories. Third, teacher-centered lecture modes usually lead to low classroom interaction and insufficient cultivation of engineering innovation capabilities.

To overcome these challenges, case-based teaching, problem-based learning (PBL), and Outcome-Based Education (OBE) concepts have gradually been introduced into engineering education reforms in recent years. Wang *et al*. pointed out that reaction engineering courses should strengthen engineering case analysis and process simulation teaching in order to improve students' engineering practice abilities[4]. Their study demonstrated that integrating theoretical knowledge with real industrial cases can significantly enhance students' understanding of complex reaction systems. Similarly, Li *et al*. reported that case-based teaching methods can effectively stimulate students' learning interest and improve classroom interaction in environmental engineering education[5]. By introducing practical environmental governance cases, students can better understand pollutant transformation mechanisms and engineering control methods, thereby improving their capability to solve complex environmental problems. In addition, the OBE concept emphasizes student-centered learning outcomes rather than simple knowledge delivery. Chen *et al*. suggested that curriculum reform under the OBE framework should focus on engineering competency cultivation and diversified evaluation systems[6]. Such educational concepts are particularly suitable for environmental engineering courses that require strong practical and interdisciplinary abilities.

Based on the above research background, this study integrates case-based teaching, PBL methods, and OBE concepts into the Environmental Reaction Engineering course. A progressive teaching system consisting of "pollution problem–reaction mechanism–kinetic analysis–reactor design–engineering optimization" was constructed. The effectiveness of the proposed teaching reform was further evaluated through teaching practice and student feedback analysis.

2. Characteristics of the Environmental Reaction Engineering Course

2.1 Course Structure and Knowledge System

The Environmental Reaction Engineering course combines knowledge from both chemical reaction engineering and environmental engineering[7]. The main teaching contents include:

- Stoichiometry and thermodynamic analysis;
- Fundamentals of reaction kinetics;
- Ideal and non-ideal reactors;
- Heterogeneous catalytic reactions;
- Heat and mass transfer processes;
- Reactor scale-up and process optimization.

Compared with conventional chemical reaction engineering courses, Environmental Reaction Engineering places greater emphasis on pollutant control processes and practical environmental applications. Therefore, students are required not only to understand theoretical models but also to apply engineering principles to environmental governance systems.

2.2 Teaching Difficulties

Several teaching difficulties are commonly encountered in this course:

- Abstract concepts such as residence time distribution and non-ideal flow models;
- Coupling mechanisms between diffusion and reaction in heterogeneous catalytic systems;
- Mathematical complexity of reactor design and kinetic modeling;
- Lack of engineering intuition among undergraduate students.

Traditional blackboard-centered teaching methods are often insufficient to help students fully understand these complicated engineering concepts. Therefore, introducing practical engineering cases and visualization tools becomes highly necessary.

3. Construction of the Case-Based Teaching System

3.1 SCR Denitrification Case

Selective Catalytic Reduction (SCR) technology is widely used for NO_x removal in coal-fired power plants[8]. In teaching practice, engineering cases related to SCR systems were introduced to help students analyze NO_x formation mechanisms, catalytic reaction kinetics, and fixed-bed reactor structures.

The following reactions were discussed during classroom teaching:

$$4NO+4NH_3+O_2 \rightarrow 4N_2+6H_2O \quad (1)$$

$$NO+NO_2+2NH_3 \rightarrow 2N_2+3H_2O \quad (2)$$

Students were further guided to analyze the influence of temperature on denitrification efficiency using the Arrhenius equation:

$$k = Ae^{\frac{-Ea}{RT}} \quad (3)$$

The engineering problem "Why does SCR denitrification exhibit an optimal temperature window?" was used as a PBL discussion topic to improve students' analytical abilities.

3.2 SO2 Catalytic Conversion Case

SO_2 catalytic oxidation was introduced as a representative case for explaining chemical equilibrium and thermal effects in exothermic reactions[8]. Through analysis of industrial sulfuric acid production processes, students learned the importance of temperature optimization and heat management in reactor operation.

The Van't Hoff equation was introduced to explain equilibrium variation:

$$\frac{dlnK}{dT} = \frac{\Delta H}{RT^2} \quad (4)$$

This case helped students understand reactor thermal stability and engineering optimization strategies.

3.3 Heterogeneous Catalytic Reaction Teaching

Gas-liquid and gas-solid reaction models were employed to explain liquid-film theory, Hatta number analysis, and coupling relationships between mass transfer and reaction processes. Visualization diagrams and simulation tools were further used to improve students' understanding of multiphase reaction systems.

4. Teaching Implementation and Evaluation

4.1 Problem-Based Learning

Engineering problems were introduced throughout classroom teaching to encourage active student participation. Questions such as "Why is there an optimal SCR operating temperature?" and "How does residence time distribution affect reactor performance?" were frequently discussed during lectures.

4.2 Simulation and Numerical Modeling

MATLAB and Aspen Plus software were integrated into the course to simulate Continuous Stirred Tank Reactors (CSTR), Plug Flow Reactors (PFR), and fixed-bed reactors. Simulation-based teaching significantly improved students' understanding of reactor performance and process optimization. For example, in PFR teaching, the design equation can be utilized:

$$\frac{dX_A}{dW} = \frac{-\gamma_A}{F_{AO}} \tag{5}$$

Help students understand the patterns of conversion rate changes.

5. Diversified Reconstruction of the Assessment and Evaluation System

To overcome the limitations of the traditional "single final examination" assessment model, a comprehensive evaluation system characterized by "whole-process assessment, multidimensional evaluation, and competency-oriented training" was established (Table 1).

Table 1: whole-process assessment

Assessment Dimension	Weight	Assessment Content and Evaluation Criteria
Process Performance	20%	Classroom attendance, participation in PBL-based random questioning, and online interaction through digital learning platforms such as Chaoxing and Rain Classroom.
Case-Based Project Assignment	30%	(1) MATLAB/Aspen modeling report (15%): evaluation of mathematical modeling and software application abilities. (2) Group engineering project presentation (15%): evaluation of complex engineering problem-solving ability, PPT presentation skills, and teamwork competence.
Final Closed-Book Examination	50%	(1) Fundamental concepts and mechanisms (20%): stoichiometry, thermodynamics, and basic equations of ideal reactors. (2) Comprehensive analytical and calculation problems (30%): emphasis on mass transfer–reaction coupling and energy balance calculations for non-isothermal reactors.

6. Conclusions

Environmental Reaction Engineering is a highly theoretical and engineering-oriented course. In this study, a progressive case-based teaching framework integrating engineering cases, PBL methods, and OBE concepts was established for environmental engineering education.

Teaching practice demonstrated that the proposed teaching model effectively improved students' understanding of complex reaction systems, enhanced engineering analysis capabilities, and increased classroom participation and learning motivation. The study provides valuable experience for curriculum reform in environmental engineering and related engineering disciplines.

Future work should focus on developing digital simulation platforms, expanding engineering case databases, and strengthening university–industry cooperation to further improve teaching quality and engineering talent cultivation.

References

[1] Liping Ma, Xiangdong Zeng. Introduction to Environmental Reaction Engineering [M]. Beijing: Chemical Industry Press, 2014.

[2] Levenspiel O. Chemical Reaction Engineering[M]. New York: Wiley, 1999.

[3] Fogler H S. Elements of Chemical Reaction Engineering[M]. Boston: Prentice Hall, 2016.

[4] Yan Li, Qiong Yang. Research on the Teaching Reform of Chemical Reaction Engineering Course [J]. Guangdong Chemical Industry, 2023,50(2):212-214.

[5] Jing Li, Qingli Zhang, Qingle Zhang. Analysis of the Application of Case Teaching Method in Environmental Law Teaching for Environmental Engineering Majors [J]. Science and Technology Innovation Herald, 2013(35):156-156.

[6] Shuhan Chen, Yongzhi He, Xiaomin Chen. Research on the Achievement and Evaluation System of Course Goals Based on the OBE Concept - Taking the Basic Course of Manufacturing Engineering as an Example [J]. Innovation Education Research.

[7] Yan Ding, Di Sheng, Lanbao Zhu, Li Ma, Xiaomei Chang. Teaching Reform and Practice of "Environmental Chemistry" Course under the OBE Concept [J]. Education and Teaching Forum, 2022(22):97-100

[8] Qin Zhong. Flue Gas Desulfurization and Denitrification Technology and Engineering Examples [M]. Chemical Industry Press, 2007.