International Journal of Education and Humanities
ISSN: 2770-6702 | Vol. 16, No. 1, 2024

Application Exploration of the CDIO Model in Laboratory Teaching of Water Pollution Control Engineering

Jiao Chen[1], Xiaobo Yang[2], Xiaochun He[2, *], Mingjiang Peng[1], Yixin Lu[1]

[1] School of Materials and Environmental Engineering, Chengdu Technological University, Chengdu 611730, China
[2] Chengdu Keya Wastewater Treatment Co., Ltd., Chengdu 610200, China
[*] **Corresponding Author**

Abstract: The laboratory teaching of water pollution control engineering holds an important position in this course and the environmental science and engineering major. In response to the existing problems in the laboratory teaching of water pollution control engineering, a reform path based on the CDIO (Conceive-Design-Implement-Operate) model has been proposed. The feasibility and practical effects of applying the CDIO concept to the laboratory teaching of water pollution control engineering have been explored. The results showed that the application of this model can effectively enhance students' interest in learning, hands-on ability, and the ability to solve complex engineering problems. It provides beneficial insights for the reform of experimental course teaching and promotes its development towards innovative models of engineering education.

Keywords: CDIO Model; Water Pollution Control Engineering; Laboratory Teaching; Application.

1. Introduction

Water pollution control engineering laboratory teaching is an indispensable part of environmental science and engineering education. By offering courses in water pollution control engineering experiments, students can participate in laboratory operations, which allows them to deeply understand and master various water pollution control techniques and methods [1]. These skills are crucial for their future work in environmental protection and water resource management, and they also lay a solid foundation for better serving the country's ecological civilization construction and sustainable development strategy [2]. Therefore, this course is very important for students in the field of environmental science and engineering, and continuously exploring new teaching models is very necessary to promote the development of the course.

As an internationally recognized innovative model of engineering education, the CDIO (Conceive-Design-Implement-Operate) model has been widely applied in laboratory teaching in recent years [3-5]. This model emphasizes project-centered education methods, aiming to cultivate students' systematic engineering capabilities from concept conception to design, implementation, and operation. The application of the CDIO model helps to improve students' practical skills, teamwork ability, and innovative thinking, while also strengthening students' understanding and application of engineering knowledge, laying a solid foundation for future engineering practice. However, the application of the CDIO model in water pollution control engineering laboratory teaching is still relatively rare at present. Traditional water pollution control engineering laboratory teaching focuses more on the imparting of theoretical knowledge, lacking in the cultivation of students' practical abilities and innovative capabilities.

Therefore, based on the analysis of the existing problems in current water pollution control engineering laboratory teaching, this paper introduces the core content and implementation steps of the CDIO model, and explores how to integrate it into water pollution control engineering laboratory teaching to build a student-centered teaching system. The aim is to enhance students' interest in learning, hands-on ability, and the ability to solve complex engineering problems, providing beneficial references and insights for the reform of laboratory teaching in environmental engineering courses.

2. Problems in Traditional Laboratory Teaching

2.1. Outdated Laboratory Equipment

Many educational institutions' water pollution control engineering laboratory equipment has not been updated in a timely manner, preventing students from being exposed to the latest water treatment technologies. The lagging update of laboratory equipment is mainly reflected in the following aspects: First, the aging of equipment leads to a decline in performance, which cannot meet the needs of modern experimental teaching and scientific research, affecting the accuracy and reliability of experimental results. Second, outdated equipment cannot support the latest experimental methods and technologies, limiting the renewal of teaching content and students' access to cutting-edge knowledge. Furthermore, outdated equipment can also lead to safety hazards, increasing the risks in the experimental process. In addition, the backwardness of experimental equipment can also affect students' interest and participation in learning, as the lack of attractiveness and practicality may lead to a lack of enthusiasm for experiments. Lastly, the lagging update of equipment can also affect teachers' teaching methods and strategies, as they may not be able to use advanced equipment to demonstrate and explain complex concepts and processes. This lag not only limits students' understanding and application of modern water treatment technology but also affects their understanding of industry development.

2.2. Disconnection between Experiments and Theoretical Teaching

There is a lack of effective integration between experimental teaching and theoretical teaching, making it difficult for students to apply the theoretical knowledge they have learned to practical operations. The disconnection between water pollution control engineering experiments and theoretical teaching is specifically manifested as follows: The content of experimental courses often lags behind theoretical teaching, lacking practical demonstrations of the latest technologies and methods; the aging of experimental equipment cannot provide an operational environment that matches modern engineering practice; teachers may lack sufficient interaction and feedback when guiding experiments, resulting in students not receiving effective help when encountering operational difficulties; the teaching process overly emphasizes theoretical lectures, neglecting the importance of applying theory to experimental operations; students lack sufficient experimental opportunities to practice and verify theoretical knowledge; the curriculum arrangement is insufficient in terms of experimental class hours, limiting students' in-depth understanding and mastery of water pollution control technology; moreover, the evaluation system for experimental teaching may not be comprehensive enough to fully stimulate students' interest and attention to experimental learning. These factors work together to weaken students' overall grasp of knowledge and their ability to solve practical water pollution problems.

2.3. Insufficient Innovative Experimental Design

There is often a lack of innovation in experimental teaching, and students rarely have the opportunity for independent exploration and innovative practice. The lack of innovative experimental design is usually reflected in the following aspects: First, the content of experiments is often too traditional, lacking exploration of emerging technologies and cutting-edge scientific issues, making it difficult for students to cultivate innovative thinking and problem-solving abilities in experiments. Second, the design of experiments lacks challenge, which cannot stimulate students' curiosity and desire to explore, causing students to easily fall into a state of passively receiving knowledge in the experimental process. Third, the experimental methods and means are singular, failing to combine the characteristics of interdisciplinary integration, limiting students' abilities to understand and solve problems from different perspectives. In addition, the experimental evaluation system overly focuses on the correctness of the results, neglecting innovative attempts and error analysis during the experimental process, which may suppress students' courage to try innovatively. Finally, the lack of experimental resources and platform support limits the space for students to carry out independent design and exploration, affecting the quality and effectiveness of experimental teaching. The existence of these problems not only restricts the improvement of the quality of education and teaching but also suppresses the development of students' creativity and problem-solving abilities.

3. Core Content and Implementation Steps of the CDIO Model

3.1. Core Content

CDIO is an educational philosophy centered on the reform of engineering education. It emphasizes the integration of the four key stages of engineering practice-Conceive, Design, Implement, and Operate-into the teaching process to cultivate students' engineering practice and innovation capabilities.

Conceive: This is the initial stage of engineering education, where students learn to identify problems, propose ideas, and concepts. At this stage, students are encouraged to use their imagination, explore different possibilities, and learn how to transform these ideas into feasible solutions.

Design: The design phase involves translating concepts into specific design plans. Students need to learn how to use engineering principles and tools to design products, systems, or processes. This stage emphasizes innovative thinking, systems analysis capabilities, and adherence to design specifications and standards.

Implement: The implementation phase is about converting designs into actual products or systems. Students need to learn how to use appropriate materials and technologies to build prototypes and how to conduct testing and verification. This stage emphasizes the cultivation of practical skills and attention to engineering details.

Operate: The operation phase ensures that the designed products or systems work properly in real environments. Students need to learn how to perform system maintenance, troubleshooting, and performance optimization. This stage emphasizes understanding system performance and mastering practical operations.

Therefore, the core content of the CDIO model includes: a) Integrated Learning: CDIO encourages students to engage in integrated learning across all four phases to ensure they can fully understand the engineering process; b) Teamwork: Under the CDIO framework, teamwork is crucial. Students need to learn how to work in teams, share knowledge, and coordinate different roles and responsibilities; c) Practice-Oriented: CDIO emphasizes that practice is at the core of learning. Through laboratory work, project practice, and industrial internships, students can apply theoretical knowledge to solving real-world problems; d) Continuous Improvement: CDIO encourages students and teachers to continuously evaluate and improve the teaching process and learning outcomes to adapt to the ever-changing engineering demands; e) International Perspective: CDIO also emphasizes the cultivation of engineers with an international perspective, capable of working and communicating in a globalized environment; f) Ethics and Sustainability: CDIO education also covers engineering ethics and sustainability issues, ensuring that students consider the social, environmental, and economic impacts in their design and implementation processes.

Through the implementation of the CDIO model, students not only gain solid engineering knowledge and skills but also cultivate innovative thinking, teamwork abilities, project management capabilities, and global competitiveness, laying a solid foundation for their future engineering careers.

3.2. Implementation Steps

The implementation steps of the CDIO model typically follow the framework as shown in Figure 1. Through these steps, the CDIO model can be effectively implemented in educational practice, providing students with a comprehensive, practice-oriented learning environment and helping them become engineers capable of meeting future challenges.

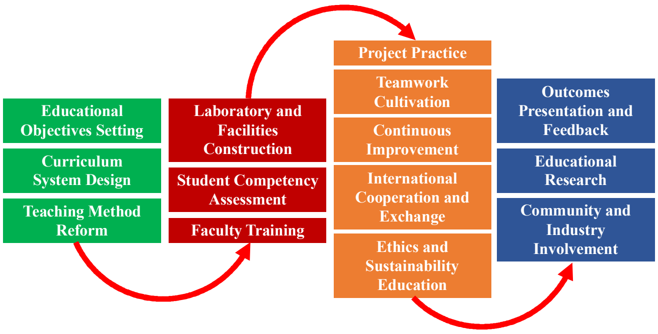

Figure 1. Implementation steps of the CDIO model

4. Practical Process Analysis

Taking the "Combined Method (Filtration, Adsorption) Wastewater Treatment Experiment" as an example, this section describes the practical process of the CDIO model in the laboratory teaching of water pollution control engineering.

4.1. Conceive

After completing the study of the theoretical knowledge of filtration and adsorption, the teacher releases the experimental topic of "Combined Method (Filtration, Adsorption) Wastewater Treatment". The teacher explains the purpose of the experiment, which includes understanding the role of filtration in turbidity removal, understanding the adsorption process and its performance, and mastering the design parameters of the combined method (filtration, adsorption) for wastewater treatment. For this topic, students are asked to think independently and then discuss in groups how to carry out the experiment. After the first round of discussion, the teacher asks a representative from each group to present the results. Based on the discussion, the three core elements of this experimental topic are identified: filtration, adsorption, and wastewater treatment. To facilitate scientific comparison, the teacher specifies the type of wastewater as wastewater containing methylene blue and suspended solid pollutants. Each group conducts a second round of discussions to address issues from the first round and refine the experimental ideas. The teacher comments on the results of the second discussion and provides answers to any questions, assisting students in completing the conception of the experiment.

4.2. Design

After the conception, students have a basic experimental idea, and the next task is to transform the idea into a specific experimental plan. To this end, the teacher guides students to start with the specific operations of filtration and adsorption to carry out the experimental design. In the selection of filtration methods, the first consideration is the filtration materials and operating conditions. In the selection of adsorption methods, the first consideration is the adsorption materials and operating conditions. The choice of filtration materials mainly includes quartz sand, river sand, activated carbon, etc. The choice of adsorption materials mainly includes zeolite sand, peanut shell powder, biochar, etc. The impact of operating conditions is mainly reflected in different influent methods, combination methods, and operation modes. As shown in Figure 2, after completing the selection of filtration and adsorption materials, the two methods are combined, the operating conditions are optimized, and the feasibility of each plan is assessed to select the best plan.

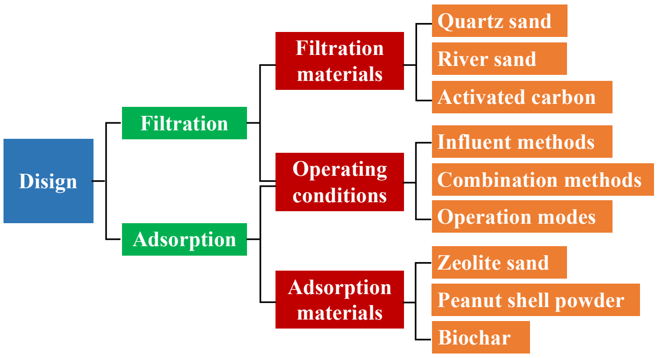

Figure 2. Design of filtration and adsorption

4.3. Implement

Firstly, a standard curve is plotted. The specific implementation steps are as follows: a) Prepare a methylene blue solution with a concentration of 50 mg/L; b) Use a UV-Vis spectrophotometer to scan the sample in the wavelength range of 250 to 750 nm to determine the maximum absorption wavelength; c) Pipette 1 to 9 mL of methylene blue solution into 50 mL colorimetric tubes, dilute with water to the mark, and measure the absorbance at the optimal wavelength using distilled water as a reference; d) Plot the standard curve with the concentration of methylene blue as the horizontal axis and the measured absorbance values as the vertical axis, and fit the standard curve equation.

Next, the wastewater is treated by filtration and adsorption. The specific implementation steps are as follows: a) Self-manufacture a filter column and fill it with 20 to 100 mL of filtration material; b) Pass 100 mL of organic dye wastewater containing methylene blue and suspended solids through the filter column, and then pour the filtered liquid into a measuring cylinder; c) Add an appropriate amount of adsorption material to the conical flask, then add the filtered organic dye wastewater, seal it, and place it in a 25°C constant temperature shaker at a rate of 160 r/min for a period of time. Stop shaking when adsorption equilibrium is reached, let it settle for 5 minutes, then filter the supernatant through a 0.45 μm filter membrane, and measure the turbidity and absorbance of the filtered liquid.

Finally, based on the changes in turbidity and methylene blue concentration before and after the combined method treatment of the wastewater, calculate the removal rate of turbidity in the wastewater by the combined filtration and adsorption method, and calculate their removal rate and adsorption amount for methylene blue in the wastewater. Compare the impact of different combination methods and operating conditions on the treatment effect, and select the optimal experimental scheme.

4.4. Operate

Table 1 reflects the removal rates of turbidity and MB by different combinations of filtration and adsorption materials. It can be observed from Table 1 that due to the differences in filtration and adsorption materials, there are also significant differences in their removal effects on water pollutants. Among them, the combination of using activated carbon as the filtration material and biochar as the adsorption material can achieve the best removal effects for turbidity and MB. The optimal operating conditions are: influent solution pH value of 10 to 11, turbidity of 200 to 500 NTU, MB mass concentration of 50 to 100 mg/L, adsorption time of 210 minutes, and reaction temperature of 25 to 30°C.

Table 1. The removal rates of turbidity and MB

Number	Filtration materials	Adsorption materials	Turbidity removal rate	MB removal rate
1	Quartz sand	Zeolite sand	88.5%	61.5%
2	Quartz sand	Peanut shell powder	90.6%	70.9%
3	Quartz sand	Biochar	94.3%	90.2%
4	River sand	Zeolite sand	92.7%	65.6%
5	River sand	Peanut shell powder	94.2%	78.8%
6	River sand	Biochar	98.1%	89.2%
7	Activated carbon	Zeolite sand	97.6%	85.4%
8	Activated carbon	Peanut shell powder	98.3%	90.1%
9	Activated carbon	Biochar	99.5%	99.8%

Unlike traditional laboratory teaching models, this case applies the CDIO (Conceive, Design, Implement, Operate) model, addressing many of the shortcomings present in traditional laboratory teaching, such as the lag in the update of experimental equipment, the disconnection between experiments and theoretical teaching, and the lack of innovative experimental design. Under limited experimental conditions, it maximizes the development of students' innovative thinking and provides a template for them to solve practical application problems.

5. Application Effect Analysis

The application of the CDIO model in the laboratory teaching of water pollution control engineering has not only enabled students to complete experiments with high quality but also led to the development of several scientific research projects, which were ultimately demonstrated through the publication of papers or the application for patents. Taking the "Combined Method (Filtration, Adsorption) Wastewater Treatment Experiment" as an example, after completing the experiment, students continued to carry out related research and applied for and were approved for three related scientific research projects, namely: the Chengdu Technological University Laboratory Open Fund Project "Preparation and experimental development of high-performance biochar water purification materials using a one-step method in a muffle furnace", the Chengdu Technological University Seedling Plan Project "High-efficiency wastewater purification system and application based on biochar-microorganism coupling", and the National College Student Innovation Training Program Project "Enhanced SBR system for wastewater purification efficiency and application by biochar-coupled microbial flora". They applied for and were granted three national patents, namely: a two-stage combined wastewater treatment system, a combined wastewater treatment device, and a microbial-biochar enhanced salinity-containing domestic wastewater treatment system. They also published two academic papers, namely "Preparation and modification of rape straw biochar and its adsorption characteristics for methylene blue in water" published in the Water journal, and "Adsorption characteristics and mechanism of methylene blue in water by NaOH-modified areca residue biochar" published in the Processes journal. In summary, the application of the CDIO model in the laboratory teaching of water pollution control engineering has achieved significant results and has good value for promotion.

6. Conclusion

This paper has conducted an in-depth analysis of the application of the CDIO (Conceive-Design-Implement-Operate) model in the laboratory teaching of water pollution control engineering, confirming its effectiveness in enhancing students' practical skills and innovative thinking. The practical reform of laboratory teaching has demonstrated that the CDIO model can stimulate students' enthusiasm for learning and strengthen their ability to address real-world engineering challenges. The CDIO model offers a new perspective and methodology for environmental science and engineering education, holding significant theoretical and practical importance for advancing innovation and development in engineering education. Moving forward, it is essential to continue exploring and refining the application of the CDIO model in laboratory teaching to cultivate more high-quality talents who meet the demands of modern engineering.

Acknowledgments

This work was financially supported by Chengdu Technological University 2024 School-Enterprise Cooperative Course (215238), Water Pollution Control Engineering I.

References

[1] Li X, Cheng X, Liu Q, et al. The cultivation and improvement of students' innovative and practical ability in the experimental teaching of water pollution control engineering[J]. Education and Teaching Forum, 2024, 18:101-104.

[2] Zhang Y, Peng Q, Qiang L, et al. Comprehensive experimental design of biological sewage treatment based on innovative talent training[J]. Laboratory Science, 2022, 25(4):28-32.

[3] She T, Chen C. Design of online and offline teaching system for piano improvisation accompaniment course for preschool education majors integrating meta-learning recommendation algorithm and CDIO[J]. Applied Mathematics and Nonlinear Sciences, 2024, 9(1):1572.

[4] Shou J. Logic and strategy for combining CDIO concept with "three innovations education" in applied universities[J]. Journal of Ningbo University of Technology, 2024, 36(2):73-78.

[5] Zhou W, Zhou Y, Tang H. Exploration of CDIO teaching mode for engineering applications[J]. The Guide of Science & Education, 2024, 16:91-93.