

Implementation and Practice of Project-Based Learning in Chemical Engineering Principles Course within Higher Education

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Abstract
The course of Chemical Engineering Principles is a very important technical foundation course for related chemical engineering majors, serving the chemical production process directly. However, in the teaching of Chemical Engineering Principles, theoretical learning and practical application are sometimes insufficiently integrated, hindering the cultivation of innovative chemical engineering talents. This article examines the application of practice of project-based learning (PBL) in Chemical Engineering Principles through the framework of project definition, implementation, and evaluation, strengthening engineering concepts and practical skills of students. The PBL practice not only consolidates professional knowledge but also improves the communication skills, technical writing abilities, and teamwork capabilities of students significantly.
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1. Introduction

The course of Chemical Engineering Principles is an engineering discipline that comprehensively applies theoretical knowledge from mathematics, physics, and chemistry to analyse and solve various unit operation problems in production. It serves as a transition from theory to engineering and also acts as a bridge between the basic disciplines and professional courses. Therefore, Chemical Engineering Principles is the core course for related majors in chemical and chemical engineering fields. The Chinese Ministry of Education explicitly advocates that curriculum development should enhance higher-order learning outcomes, emphasize innovativeness, and increase the challenge level of courses (Li *et al.* 2022). Consequently, the teaching of Chemical Engineering Principles, integrating both theory and practice, must evolve to meet the contemporary demands for engineering talent. Project-Based Learning (PBL) is recognized as a crucial pedagogical approach for achieving these objectives.

The aim of Chemical Engineering Principles is to equip students with the fundamental principles of unit operations, foster the ability to solve complex engineering problems comprehensively. However, the current teaching system faces certain challenges and needs to align with the era's requirements by integrating modern engineering education methodologies. Therefore, this article examines the application of PBL in Chemical Engineering Principles through the framework of project definition, implementation, and evaluation, strengthens students' engineering concepts and practical skills.

2. The Necessity of Implementing PBL in Chemical Engineering Principles

The Chemical Engineering Principles course covers key unit operations including fluid flow, fluid transportation, filtration, sedimentation, heat transfer, evaporation, distillation, absorption and desorption, extraction, and drying (Cao & Liu 2022). The traditional teaching approach typically dedicates individual chapters to specific unit operations, covering fundamental principles, equipment structure, and operation within each chapter. Nevertheless, a significant disconnect exists between this teaching approach and actual industrial production practices. Implementing PBL allows students to construct knowledge autonomously during the problem-solving process (Wu *et al.* 2023). This effectively enhances the scientific thinking and problem-solving capabilities of students.

3. Design of the Project-Based Learning Reform

3.1 Defining Project Tasks

During the project definition phase, the significance of the project should be explored, inherent problems are identified, and project tasks are clearly delineated (Luo *et al.* 2025). Content of moderate difficulty should be selected from the unit operations to formulate the project task specifications. These specifications must align with the theoretical course progression and remain within the students' capabilities. Teachers can design subprojects of varying difficulty levels within the main project theme, allowing students to choose a suitable challenge level, thereby enabling differentiated instruction. For instance, within the fluid flow unit, a main project like "Urban Water Supply Optimization" can include subprojects such as "Pipe Sizing Selection", "Fluid Transportation Equipment Selection" and "Fluid Transportation Energy Calculation". This guides students in divergent thinking and increases their interest in learning about fluid transportation machinery. Furthermore, a single project task can integrate multiple unit operations. For example, a project centered on “School Bathhouse Water Supply System” could use heat transfer as the main theme while incorporating water pipeline design as a subproject, thereby linking heat transfer and fluid flow unit operations, which helps students review key concepts from momentum transfer and achieves cross-integration of knowledge.

3.2 Project Implementation

The guiding principle of PBL is to assign an independent project to students, with the teacher acting as a facilitator, enabling students to autonomously manage and complete each stage (Yang *et al.* 2023). Consequently, the implementation process imposes requirements on both instructors and students. Firstly, students clarify the tasks they need to research and complete based on the project specifications provided by the teacher, facilitating better workflow organization. Secondly, the teacher forms balanced project teams, which should combine students with strong analytical skills and those of average ability. Each team elects a leader responsible for task allocation, coordination, and implementation. Clear division of labor, active communication, and mutual learning among team members are essential. To ensure genuine participation from all students, each individual must independently submit their project deliverables. Thirdly, during project execution, students conduct literature reviews, synthesize information, perform calculations specified in the task document, and discuss their results.

3.3 Project Evaluation and Summary

The evaluation is a vital component of PBL. Students are encouraged to present their work in report format. Assessment employs a combined approach: student self-assessment (30%), peer assessment within/between groups (30%) and teacher final assessment (40%). The evaluation shifts focus away from instructor-centric assessment by incorporating group and peer evaluation. By comparing the strengths and weaknesses of outcomes of different groups, students are guided to refine and improve their own designs by learning from others. This PBL practice combined with inter-group peer review stimulates students’ interest in the chemical industry. The PBL practice not only consolidates professional knowledge but also improves the communication skills, technical writing abilities, and teamwork capabilities of students significantly.

4. Conclusion

Within the PBL framework, the teacher transitions from being the sole center of traditional teaching to becoming an organizer, supervisor, and learning facilitator. PBL emphasizes the student as the primary cognitive agent, demanding higher pedagogical competence from the teacher. Teachers should possess not only solid theoretical knowledge but also strong design and operational skills. Implementing PBL helps students understand how theoretical knowledge solves real-world problems, their learning motivation is stimulated, their learning objectives become clearer, and teaching effectiveness is demonstrably enhanced.

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