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Reform and Exploration of "Principles of Chemical Engineering" in Accordance with the Standards of Engineering Education Accreditation

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Abstract: *In response to the construction of emerging engineering education, we based on the OBE (Outcome-Based Education) teaching philosophy of 'student-centered, output-oriented, and continuous improvement', we have carried out a series of educational reforms for the 'Principles of Chemical Engineering' course in accordance with the standards of engineering education accreditation. Focusing on enhancing students' ability to solve complex engineering problems, we have conducted a series of explorations in the formulation of the teaching syllabus, restructuring of teaching content, innovation in teaching methods, and the construction of a diversified evaluation system. Through three years of practice, we have achieved certain results, laying the foundation for the construction of a high-quality 'Principles of Chemical Engineering' course.*

Keywords: *Principles of Chemical Engineering; Emerging engineering education; Outcome-Based Education (OBE) Teaching Philosophy; Engineering Education Accreditation*

1. Introduction

Against the backdrop of the construction of emerging engineering disciplines, our college launched reforms in the training program aimed at engineering education accreditation in 2020. After more than a year of research and preparation, the new training program was implemented in the fall semester of 2021. As a core course for the Chemical Engineering and Technology major, "Principles of Chemical Engineering," we proposed the creation of a first-class offline course and carried out a series of educational reforms based on the OBE (Outcome-Based Education) teaching philosophy of "student-centered, output-oriented, continuous improvement," in accordance with the standards of engineering education accreditation. Focusing on enhancing students' abilities to solve complex engineering problems, we have carried out a series of reforms in the formulation of the teaching syllabus, restructuring of teaching content, innovation in teaching methods, and construction of a diversified evaluation system. Through classroom teaching practice for undergraduate students from 2021 to 2023, we have achieved certain results and have helped our major in Chemical Engineering and Technology pass the national engineering education accreditation in 2023. Below, we discuss specific measures in building a high-quality "Principles of Chemical Engineering" course.

2. Develop teaching syllabus that meets the requirements of engineering education accreditation.

"Principles of Chemical Engineering" is a required course and a core foundation class for the Chemical Engineering and Technology major. It primarily covers chemical engineering unit operations such as fluid flow, fluid transportation machinery, sedimentation, filtration, heat transfer, absorption, distillation, and drying. Through study, students will gain a proficient understanding of the basic principles, operational characteristics, equipment performance, and industrial applications of these unit operations. They will be able to use material balance and heat balance calculations to design and compute the processes and equipment for unit operations, laying the groundwork for further study in specialized courses such as Chemical Reaction Engineering, Chemical Separation Engineering, Chemical Process Engineering, course design for Principles of Chemical Engineering, and graduation projects. The course plays an important role in developing students' engineering capabilities and qualities, innovative thinking, and innovation and entrepreneurship skills. In recent years, improving the teaching quality of Principles of Chemical Engineering has garnered widespread attention in educational reforms[1][2][3][4].

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Starting from 2020, after extensive research and discussions with corporate engineers and alumni, we understood the economic characteristics of the Pearl River Delta region of China and the demands for chemical engineering talents. We established a teaching and research section for engineering capability training and a course group for "Principles of Chemical Engineering," and developed a syllabus for "Principles of Chemical Engineering" that complies with engineering education accreditation. The syllabus underwent several rounds of review and defense by experts and was finally approved by the university.

The highlight of the new syllabus is that we established five teaching objectives that support the graduation requirements of the training program (see Table 1) and broke them down into each chapter's teaching content. Teachers in charge organize the teaching content and prepare lesson plans according to the syllabus.

Table 1: Curriculum objectives and supporting graduation requirements

No	Course Objective	Supporting Graduation Requirement Indicator	Graduation Requirement
1	Objective 1: Master the basic concepts and principles of chemical engineering unit operations, and be able to apply them to the understanding, expression, and analysis of complex chemical engineering processes.	1.3 Be able to use relevant knowledge and mathematical modeling methods to deduce and analyze complex engineering problems in the field of chemical engineering and technology.	1 Be able to apply mathematics, natural sciences, engineering foundations, and professional knowledge of chemical engineering and technology to solve complex engineering problems in chemical product development and chemical production processes.
2	Objective 2: Be familiar with common chemical engineering unit operation processes and equipment characteristics, and have the ability to identify and judge chemical engineering unit operations and perform process calculations.	2.1 Have the ability to identify and judge complex engineering problems in the field of chemical engineering and technology.	2 Be able to apply the basic principles of mathematics, natural sciences, and chemical engineering science to identify, express, and through literature research, analyze complex engineering problems in the field of chemical engineering and technology to obtain effective conclusions.
3	Objective 3: Learn to use material balance equations, heat balance equations, Bernoulli's equation, heat transfer equations, mass transfer equations, and equilibrium equations to conduct comprehensive analysis and solutions for complex chemical engineering processes.	2.2 Have the ability to express, analyze, and solve complex engineering problems in the field of chemical engineering and technology.	
4	Objective 4: Be able to comprehensively apply the basic principles of momentum transfer, heat transfer, and mass transfer to analyze complex problems in the field of chemical engineering and technology, propose solutions, and obtain effective conclusions.	2.3 Be able to use basic principles and with the aid of literature research, analyze complex engineering problems in the field of chemical engineering and technology, seek possible solutions, and obtain effective conclusions.	
5	Objective 5: Learn to track literature or understand the latest technology and development trends of chemical engineering unit operations.	12.2 Pay attention to the development of the field related to chemical engineering and technology, have the ability for independent learning, including the ability to understand technical issues, summarize, and raise questions, etc.	12 Have the awareness for independent and lifelong learning, pay attention to the technological progress in chemical engineering and related fields, and have the ability to continuously learn and adapt to development.

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In the implementation of these teaching objectives, we have also specifically introduced innovation and entrepreneurship education to comprehensively create a high-quality teaching system. This aims to cultivate students' abilities in the following areas:

(1) Mastery of solid engineering foundation knowledge, enabling students to understand the basic concepts and principles of momentum transfer processes, heat transfer processes, and mass transfer processes through learning, and to apply them to analyze, identify, and solve practical problems in complex chemical engineering processes.

(2) Possessing the qualities of an outstanding engineer, capable of solving complex engineering problems, through learning, students can analyze typical unit operations, perform design calculations, and select equipment to solve practical problems in the chemical engineering profession.

(3) Possessing innovative and entrepreneurial thinking and abilities, through learning, students have the capacity for scientific inquiry and independent learning, can keep up with the latest industry technology development and product innovation, stimulate interest in innovation and entrepreneurship, and enhance the comprehensive application of knowledge.

3. Implementing Innovation and Entrepreneurship Education in Classroom Teaching

Course Objective 5 underscores the necessity of integrating innovation and entrepreneurship education into curriculum teaching, which is one of the essential components of studying the Principles of Chemical Engineering. It also highlights the significance of innovation and entrepreneurship education in cultivating the capabilities of outstanding engineers in students. The question of how to implement these elements into everyday teaching activities is something that we, as instructors, must face.

Firstly, instructors should possess solid engineering knowledge and a broad perspective in their field. They should also have practical engineering experience in enterprises to understand the latest industry technologies and development trends. Teachers lacking this experience should participate more in industry-academia-research activities, consult relevant industry research and development progress, and extract teaching cases in line with their research directions. By integrating these cases with textbook content, they can formulate feasible lesson plans and implement them into routine classroom teaching.

Below are a few examples illustrating how we can implement innovation and entrepreneurship education into classroom teaching. We use the textbook "Principles of Chemical Engineering," edited by Wang Zhikui and published by the Chemical Engineering Press. We have organically interwoven several cases in accordance with the content of each chapter for specialized discussions in the classroom.

3.1 Research Progress on Fluid Turbulence Theory and Its Impact on Heat and Mass Transfer Technology (Chapter I)

In our textbook, the first chapter only introduces the concepts of laminar and turbulent flow in terms of fluid flow types, preventing students from understanding the past, present, and future development of these theories. In 1883, the French scientist Reynolds conducted the famous Reynolds experiment, which revealed the two basic types of fluid flow to people. However, after more than 100 years of research on turbulence, people still cannot fully grasp its basic laws. The famous turbulence N-S equations are still unsolvable mathematically, making the study of turbulence a problem of the century. At the same time, in our subsequent studies, we widely use the knowledge of turbulence to solve heat and mass transfer technology problems. Therefore, we combine the classics in the classroom and introduce this case, aiming to stimulate students' interest in scientific research, enrich classroom teaching content, and provide a good inspiration for cultivating students' innovative spirit.

3.2 Fluid Explosion-Proof High-Pressure Conveyance Equipment - Diaphragm Pump (Chapter II)

Chapter II of textbook introduces other chemical industry pumps, with the classic introduction of centrifugal pumps, reciprocating pumps, etc., without mentioning diaphragm pumps. However, in conjunction with the latest technological developments in the chemical industry and the fact that many of our students work in coating and ink factories after graduation, these enterprises extensively use flammable and explosive organic solvents. From a safety perspective, it is essential to use

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explosion-proof conveyance equipment. The textbook does not contain relevant content to introduce this technology, and we believe it is very necessary to explain it to students in class to instill the concept of safe production.

3.3 New Heat Pipe Heat Transfer Technology and Its Application in Solar Water Heaters (Chapter IV)

Chapter IV of textbook introduces heat exchangers, the principles of various heat exchangers are listed, traditionally focusing mainly on shell and tube heat exchangers, plate heat exchangers, etc. However, it does not adequately cover the latest heat pipe technology and its applications. The technology to improve heat transfer efficiency has always been a hot topic in academic research because it has broad application prospects in both industrial and consumer products. In our classes, combining the latest technology in solar energy utilization, we introduce the principles and applications of heat pipes, enhancing students' ability to grasp the latest heat transfer technology and their interest in new technologies. This also introduces a typical case to cultivate students' abilities to analyze and solve problems.

3.4 Steam Distillation Technology with Steam Stripping and Its Application in the Separation of Natural Fragrances (Chapter VI)

Chapter VI of the textbook mentions the concepts of constant boiling points in non-ideal solutions, batch distillation, and azeotropic distillation. However, these traditional pieces of knowledge are not easily understood by students, let alone applied. Traditional distillation techniques cannot solve the separation problems of natural fragrances. The high boiling points, susceptibility to decomposition, and oxidation of natural fragrances and some organic compounds result in poor quality and effectiveness of ordinary distillation separation. We have introduced the latest industry achievement, steam stripping azeotropic distillation technology, into the classroom, allowing students to understand classic concepts such as non-ideal solutions, azeotropes, constant boiling points, stripping, and azeotropic distillation. At the same time, exposing students to the latest application technologies increases their interest in learning and cultivates their ability to solve practical problems.

The teaching examples listed above serve only as an introduction. Teachers can, based on their own knowledge and experience, organically integrate content related to innovation and entrepreneurship education into lesson plans and classroom teaching. This enriches teaching methods and improves teaching effectiveness.

4. Innovative Teaching Methods and Techniques

"Principles of Chemical Engineering" is a foundational professional course that utilizes advanced mathematics, college physics, and physical chemistry basics. It can be quite dry, and many students do not have a high interest in studying it. Traditional innovative teaching methods and means, such as establishing learning websites, enriching learning resources, using Cloud Classroom Learning App for teaching, and a mix of online and offline instruction, can have certain effects and are what many teachers are working on. Our course in Principles of Chemical Engineering has also been doing this, so we will not delve deeply into the discussion here. However, we believe that improving the effectiveness of classroom teaching can better stimulate students' interest in learning and achieve good teaching results. Below, we focus on introducing how we flexibly apply the following teaching methods in classroom teaching design.

4.1 Harness the Personal Charm of the Instructor

Why do teenagers chase after celebrities? It's because celebrities possess personal charm in their eyes, which leads to their admiration. Everyone has idols, and our students, around 20 years old and in the prime of their youth, desperately need the reflection of the teacher's personal charm within them. For popular courses, students have a high interest in learning, which makes teaching much more effective. Enhancing personal charm is related to the instructor's ethics, character, values, and the breadth of knowledge, which is easier said than done. In the teaching of Principles of Chemical Engineering, instructors should strive to improve their personal cultivation and fully display their personal style in the classroom, striving to become teachers whom students like and admire.

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4.2 Introducing Humor into the Classroom

Humor is the most effective way to regulate the classroom atmosphere, stimulate interest in learning, and showcase personal charm. Teachers should use some humorous language in class at the right time and to a proper extent to interact with students, which can achieve a result with half the effort. However, it is crucial to combine humor with the teaching content, not for the sake of being humorous, and the key lies in the control of the degree.

4.3 Analogy Teaching Method

There are many difficult points in the curriculum that are not easy to understand, and it is difficult to explain them clearly during class. An analogy teaching method can be adopted. For example, in the teaching of heat conduction in Chapter 4, it is hard for students to understand the heat conduction through multiple flat walls. We introduced the concept of series and parallel heat paths, comparing them with the series and parallel circuits they have learned in college physics. The heat transfer rate (corresponding to electric current), the driving force of heat transfer (corresponding to voltage), and the thermal resistance (corresponding to electrical resistance) can be used to apply the knowledge of electrical circuits learned by students to heat transfer. Students can easily remember this, and the effect is excellent.

4.4 Inductive, Summarizing and Discriminating Teaching

In the curriculum, there are many similar or related concepts in the same chapter or throughout the course, which students cannot distinguish or easily confuse. In class, we repeatedly emphasize that students must learn to induce, summarize, and identify in order to improve. For example, regarding fluids: compressible fluids, in-compressible fluids, ideal fluids, Newtonian fluids, and non-Newtonian fluids, these are similar concepts that appear in different parts of the same chapter. By listing them together and asking students to summarize and categorize, students quickly understand.

4.5 Introducing Fashion and Hot Technology Topics into the Classroom

Students are very interested in new knowledge, new fashion, and contemporary hot technology topics. In our classroom teaching, we combine these new contents with the textbook as the times change, which quickly stimulates students' interest in learning. The classroom becomes lively and allows students to expand their academic horizons. For example, when talking about heat transfer enhancement, we introduced the cooling technology of computer CPU, why Google built its servers in Finland, and the cooling issues of Tesla electric car batteries by Elon Musk. Students were captivated, and the teaching effect was improved

4.6 Expanding Online Search to Enhance Students' Ability to Acquire Knowledge Independently

Making full use of online search, we encourage students to look up relevant literature on the internet based on the textbook content and write reading reports. This is an effective way to cultivate students' self-learning ability, increase their interest in learning, and leverage their strengths. For example, in class, we assigned an extracurricular homework titled "Progress in the Application of Static Mixers for Enhanced Heat Transfer." Students were asked to search online for relevant information and write a report of no less than 800 words.

4.7 Have the Ability to Dissect and Simplify Complex Issues

The teaching materials are extensive, but the class hours are limited. How to clearly and thoroughly explain the content within the limited time of teaching, and to ensure that students can understand and comprehend is indeed a test of the teacher's ability, especially for professional courses in engineering that involve a large amount of advanced mathematics, which increases the difficulty of classroom teaching. The teacher must have a profound and comprehensive professional knowledge to be able to dissect and simplify complex issues, and have the ability to organize the teaching content, to vividly and effectively impart knowledge to students. Otherwise, it is easy to fall into the situation where students feel that the teacher is just reading from the textbook, and then there is no talk of teaching effect。

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5. Diversified Evaluation System for Teaching Effectiveness

In the syllabus of Chemical Engineering Principles, we have established an evaluation system for the course objectives. Daily performance, extracurricular assignments, papers written outside class, and final exams are all included in the assessment scores. We also adopt the analysis method of engineering education certification achievement to evaluate the teaching effectiveness, which serves as the basis for continuous improvement. For details, see Table 2 and Figure 1.

Table 2: Assessment Content and Grade Proportions of Chemical Engineering Principles Course Objectives

No	Course Objective (Supporting Graduation Requirement Indicator Point)	Assessment Content	Basis for Evaluation and Grade Proportion (%)			Total (%)
			Usual	Homework	Exam	
1	Objective 1: To master the basic concepts and principles of chemical engineering unit operations and apply them to the understanding, expression, and analysis of complex chemical engineering processes. (Supporting Graduation Requirement Indicator Point 1.3)	Master the basic concepts and principles of unit operations such as fluid flow, fluid transportation, sedimentation, filtration, heat transfer, absorption, distillation, and drying.	10		21	31
2	Objective 2: To be familiar with the common processes and equipment characteristics of chemical engineering unit operations and have the ability to identify, judge, and perform process calculations for chemical engineering unit operations. (Supporting Graduation Requirement Indicator Point 2.1)	Master the processes and equipment characteristics of chemical engineering units, identify and judge the types of unit operations, and perform process calculations.		10	14	24
3	Objective 3: To learn to use material balance equations, heat balance equations, Bernoulli's equation, heat transfer equations, mass transfer equations, and equilibrium equations for comprehensive analysis and solution of complex chemical engineering processes. (Supporting Graduation Requirement Indicator Point 2.2)	Use material balance, heat balance, Bernoulli's equation, heat transfer equations, mass transfer equations, and equilibrium equations for comprehensive calculation and solution of complex chemical engineering processes.			21	21
4	Objective 4: To be able to use the basic principles of momentum transfer, heat transfer, and mass transfer to analyze complex problems in the field of chemical engineering and technology, propose solutions, and obtain effective conclusions. (Supporting Graduation Requirement Indicator Point 2.3)	Use transfer principles to analyze complex chemical engineering problems and propose solutions.			14	14
5	Objective 5: To learn to track or understand the latest technology and development trends of chemical engineering unit operations through literature. (Supporting Graduation Requirement Indicator Point 12.2)	Master the ability to search, analyze, and summarize literature on chemical engineering unit operation technology.		10		10
Total			10	20	70	100

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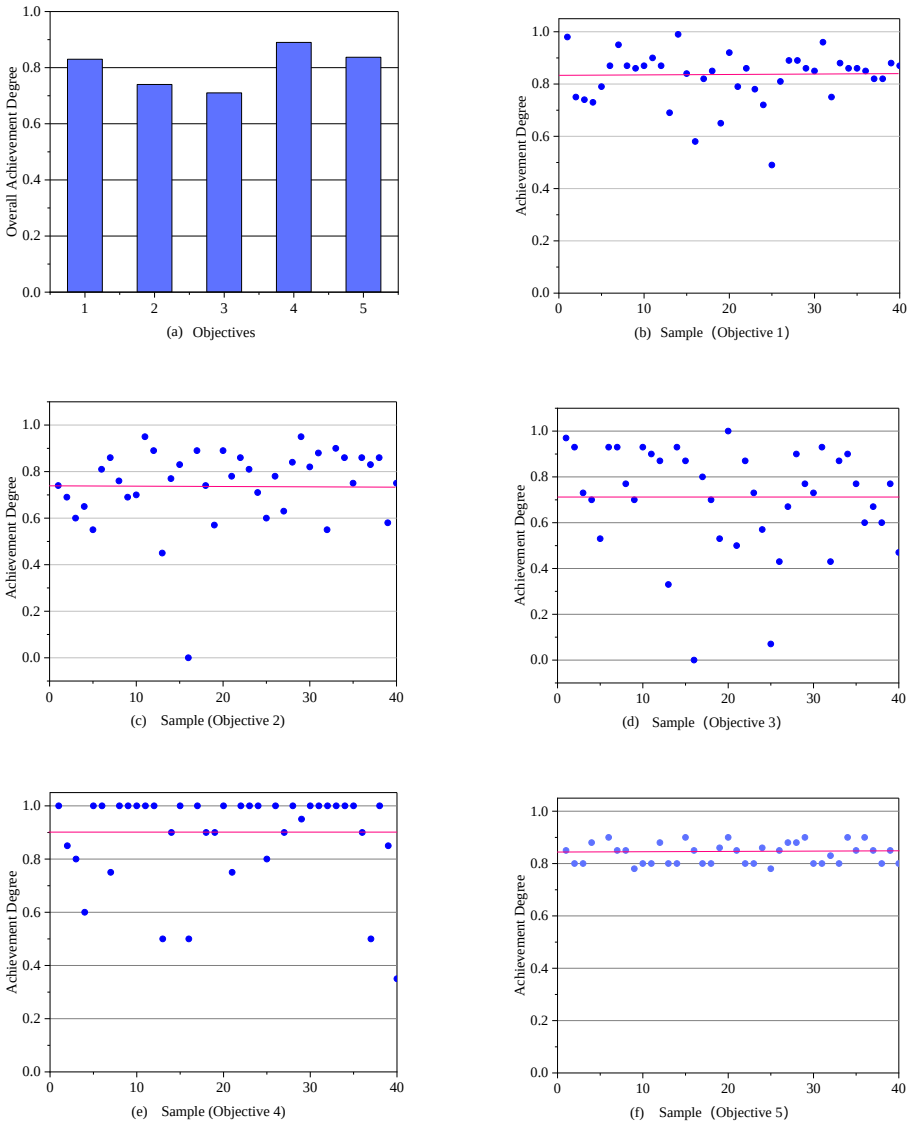

Figure 1: Achievement Degree of Course Objectives for the Chemical Engineering and Technology Major Class 211106 at Our School: (a) Overall Achievement Degree of Course Objectives; (b) Distribution of Achievement Degree for Course Objective 1; (c) Distribution of Achievement Degree for Course Objective 2; (d) Distribution of Achievement Degree for Course Objective 3; (e) Distribution of Achievement Degree for Course Objective 4; (f) Distribution of Achievement Degree for Course Objective 5.

Through achievement degree analysis, we can conveniently evaluate the teaching effectiveness, understand the weakest aspects of students' learning, and provide a reliable basis for continuously improving teaching content and strengthening learning guidance. In addition to this, we also evaluate the teaching effectiveness through student discussions and surveys.

6. Summary

Over the span of three years, through teaching practice with nearly 150 undergraduate students across three cohorts in the Chemical Engineering and Technology major at our school, we believe that the reform measures to create a first-class offline course "Principles of Chemical Engineering" are feasible and have achieved significant teaching effectiveness. On the foundation of learning basic knowledge, we adhere to the orientation of moral education, integrate elements of ideological and political education, cultivate students' patriotism, environmental awareness, and scientific spirit; introduce innovation and entrepreneurship education, which fosters students' abilities to analyze and

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solve problems, expands their innovative thinking, highlights the innovation and cutting-edge nature of the course, stimulates students' interest in academic and engineering application research, and provides strong support for training excellent chemical engineers; flexibly adopt a variety of teaching methods, build a diversified evaluation system, reform the evaluation items and subjects, and truly implement the OBE teaching philosophy of "student-centered, output-oriented, continuous improvement," benefiting a wide range of students.

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References

[1] Helin Pan, Jie Huang, Yanyang Wu, Yulan Liu, Yitian Zhu. Exploration and Practice on Ideological and Political Teaching of Chemical Engineering Principle Course [J]. University Chemistry, 2019, 34(11): 113-120. doi: 10.3866/PKU.DXHX201910028

[2] Liu Hongmei, Han Yongping, Hou Chunjuan. Innovative Design of Chemical Engineering Principles Teaching in Pharmaceutical Engineering Specialty under the Background of New Engineering Construction [J]. Chemical Education,2022, 43(4): 101-106

[3] Cuijuan Zhang, Tao Liu, Shanghua Feng. Design and Practice of Integrated Teaching of Chemical Engineering Principle Experiment under the Background of Professional Certification-Taking Absorption as an Example[J]. Frontiers in Educational Research, 2023, 6(24); doi: 10.25236/FER. 2023. 062403.

[4] Liu Hui, Cao Zhanfang, Zhong Hong. Reform and practice of experiment teaching of chemical engineering principle based on subject competition [J]. Higher Education in chemical engineering, 2020(1): 123-127.