Teaching Reform of "Food Engineering Principles" Course Based on CDIO Concept

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Abstract: Based on CDIO concept, the teaching reform of "Food Engineering Principles" course was explored. The teaching process was planned following the logic of "Conceive-Design-Implement-Operate". In the "Conceive" stage, training objectives, graduation requirements, curriculum system and their supporting relationship were fully considered. In the "Design" stage, the knowledge system was constructed based on engineering projects through decomposing the design process of unit operation equipment, and the integrity of theoretical course, experimental course and project design was strengthened. In the "Implement" stage, through project-driven teaching combined with diversified teaching methods and virtual simulation experience, students were guided to carry out problem-oriented thinking, curriculum politics were integrated into knowledge teaching, and the process assessment was strengthened. In the "Operate" stage, cooperation mechanism, guarantee mechanism and supervision mechanism were established to ensure the effective development of teaching. The aim was to cultivate students' ability to analyze and solve problems related to food engineering practice, responding to the training needs of high-quality innovative and applied talents.

Keywords: "Food Engineering Principles" Course; Teaching Reform; CDIO Concept; Unit Operation Equipment; Project-Driven

1. Introduction

With the rapid growth of China's economy, implementing the strategy of reinvigorating China through human resource development in the new era and cultivating high-quality talents with the background of new engineering, are important measures to promote the rapid development of the country and accelerate the process of industrialization [1]. Universities and colleges have the responsibility to continuously optimize the professional cultivation mechanism to meet the needs of industry and social transformation [2]. "Food Engineering Principles" course is a basic engineering course for food science and engineering related majors. It aims to cultivate students' ability to analyze and solve problems related to food engineering practice, and lay a solid foundation for students to engage in related industries. The course is based on the "Three-transfer Theories" (momentum transfer, heat transfer, mass transfer), and teaches the basic principles, calculation, design and selection of common unit operation equipment in food production and processing. CDIO concept advocates that in the process of talent cultivation, the life cycle of engineering projects should be taken as the carrier, and students should be guided to learn and think actively in the teaching practice, so as to improve the ability of analyzing and solving engineering problems. Exploring the teaching reform of "Food Engineering Principles" course based on CDIO concept will help cultivate innovative and applied talents with solid theoretical knowledge and practical skills.

2. Current Teaching Situations

In the field of engineering education, researches of teaching modes present the characteristics of diversification and innovation. With the continuous updating of educational concepts and the rapid development of educational technology, there were multiple attempts in the teaching reform of "Food Engineering Principles" course. Based on the concept of learning-centered, Wang Baobei et al carried out the teaching reform of "Food Engineering Principles" course through stimulating learning interest by means of preview guidance, case teaching, mind mapping and other multiple means, guiding students to actively learn and summarize knowledge points in time, and used group work to improve the ability of problem solving and teamwork [3]. Ding Chunming et al designed a hierarchical teaching model of “Food Engineering Principles” course according to the variety and differences in learning foundation and mastery ability of the teaching classes [4]. To improve students' engineering practice ability, Li Min et al took students as the center during the topic selection of “Food Engineering Principles” project design course, integrated virtual reality technology into teaching, and established a process-diversified assessment system [5]. Based on OBE concept, Wu Jun et al constructed a “Food Engineering Principles" teaching system combined with theoretical knowledge, experimental teaching, project design and discipline competition, so as to improve students' ability to solve complex engineering problems [6]. The focus of the existing researches was mainly on the study of an independent course, and the connection with engineering practice still needed more emphasis. As one of the core courses of food science and engineering related majors, “Food Engineering Principles” course is usually set up in the form of a trinity of theoretical course, experimental course and project design, and however the overall teaching reform research is insufficient.

3. The Connotation and Application Value of CDIO Concept

CDIO concept is an innovative engineering education concept founded by the joint research of four universities, including Massachusetts Institute of Technology and Royal Swedish Institute of Technology. CDIO represents “Conceive”, “Design”, “Implement” and “Operate”. It systematically puts forward standards of ability training, comprehensive implementation, inspection and evaluation, with high operability and measurability [7].

3.1 The Connotation of CDIO Concept

CDIO concept integrates the life cycle of engineering projects into teaching, combines the principles of “project-based teaching and practice” and “learning by doing”, fully mobilizes learning initiative and enthusiasm, and cultivates students' technical knowledge, reasoning ability, professional ability and attitude, teamwork ability, and engineering practice ability [8,9]. As an engineering basic course for food science and engineering related majors, “Food Engineering Principles” focuses on the cultivation of engineering practice ability, which is consistent with the goal of CDIO concept.

3.2 The Application Value of CDIO Concept

Improve teaching quality and effectiveness. CDIO concept advocates that teachers are not only the imparter of knowledge, but also the inductor and collaborator of students' learning process. Integrating engineering projects into teaching help stimulate students' learning interest and initiative, guide students to deepen their understanding of theoretical knowledge and master its applicable scenarios and methods.

Enhance comprehensive quality and employment competitiveness. College graduates cultivated by the traditional education modes often lack practical experience and innovation ability, which is difficult to meet the rapidly changing needs of modern food engineering. By project-driven teaching which closes to actual production, students participate in the project life cycle in the form of teamwork, with problem-oriented thinking, engineering practice ability and comprehensive quality cultivated.

Promote deep integration of industry, university and research. Teaching activities are integrated with college-enterprise cooperation projects. The teaching content and methods are able to be adjusted dynamically according to the industry development. Students participate in the process of engineering problem solving, and grasp the technological and development trends of the industry. The deep integration of industry-university-research and teaching brings innovative ideas and technical support to enterprises, and cultivates qualified talents for the development of new productivity.

Some scholars have already tried to integrate CDIO concept into engineering education. Wang Yuxin et al applied CDIO concept to the teaching design of instrumental analysis experiment course, and discussed the influence of CDIO teaching method on students' learning attitude and achievement, as well as teachers' career development [10]. Zheng Yanyan et al reconstructed the “Polymer Engineering” practice course on the basis of CDIO framework, and integrated the life cycle of biodegradable 3D printing filaments into teaching activities [11].

4. Teaching Reform Based on CDIO Concept

“Food Engineering Principles” course generally teaches relevant knowledge and skills of typical unit operations in the order of momentum transfer, heat transfer and mass transfer. Typical unit operations include fluid flow and transportation, sedimentation and filtration, stirring and mixing, heat transfer, evaporation and crystallization, absorption, distillation, extraction, drying, freezing, etc. Due to the limitation of class hours and experimental equipment, colleges usually combine their own discipline orientation and research expertise to determine the focus of teaching content. The following matters need to be paid attention to in the teaching process. Learning heat transfer requires some momentum transfer knowledge. For example, heat convection is affected by the flow state of the fluid. Learning mass transfer requires some knowledge of momentum transfer and heat transfer. For example, the design of mass transfer tower needs to consider fluid mechanics characteristics, heat exchange and other issues. The advantage of traditional teaching mode is that the knowledge context is clear and easy to remember. The disadvantage is that the three transfer processes are loosely connected at the application level. The design, implementation, operation and maintenance of most unit operation equipment in engineering practice involve two or more transfer processes. CDIO concept can provide solution to above drawbacks. In the following teaching reform practice, the teaching process was planned on the basis of "Conceive-Design-Implement-Operate", tightly responding to the training objectives and graduation requirements. The knowledge system was constructed based on design projects of unit operation equipment, carrying out theoretical course, experimental course and project design in a closely linked way. Project-driven teaching combined with diversified teaching methods and virtual simulation experience guided students to carry out problem-oriented thinking. Curriculum politics were integrated into knowledge teaching. Process assessment was strengthened Cooperation mechanism, guarantee mechanism and supervision mechanism were established to ensure the effective development of teaching.

4.1 Planning the Teaching Process

Following the logic of "Conceive-Design-Implement-Operate", the teaching process of “Food Engineering Principles” course was planned, as shown in Figure 1.

4.1.1 Conceive

Teaching began with the formulation of cultivation program, which put forward cultivation objectives and graduation requirements, and set up a curriculum system for support. Different professional directions have different requirements for the mastery of knowledge and skills related to the course. For example, compared to food safety and nutrition major, food engineering major requires more comprehensive and detailed study of the course, which may be reflected in the class hours and assessment difficulty. To ensure the integrity and continuity of the curriculum system, the internal relations between “Food Engineering Principles” and “Physics”, “Food Technology”, “Food Machinery”, “Engineering Drawing”, “Food Factory Design” and other related courses needed to be sorted out. The teaching syllabus clarified the supporting relationship between teaching content and cultivation objectives including basic knowledge, personal ability, interpersonal team ability and engineering system ability.

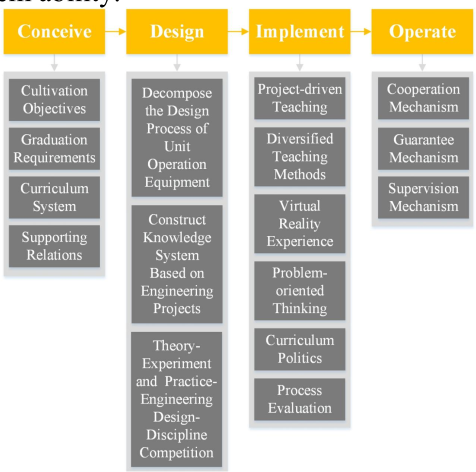

Figure 1. The Teaching Process Based on CDIO Concept

4.1.2 Design

The design process of the unit operation equipment included raw materials and technical routes, process flow design, material constant calculation, energy constant calculation, process design and selection of equipment, workshop layout design, chemical pipeline design, non-process design, preparation of design documents, etc. Based on the colleges' discipline orientation and research expertise, combined with problem solving process of actual engineering cases, the knowledge system of “Food Engineering Principles” course was constructed with strong integrity of theoretical course, experimental course and project design, so as to realize the gradual progress of “Theory-Experiment and Practice-Engineering Design-Discipline Competition”. At the same time, the connection and differences with the relevant pre and post courses were ensured to reduce repeated and inefficient teaching. Students could deepen their understanding of theoretical knowledge in actual application scenarios and establish a cognitive paradigm that was easy to be traced back. The specific case of knowledge system construction would be discussed in chapter 4.2.

4.1.3 Implement

Through project-driven, inquiry-based, case-based and other diversified teaching methods, supplemented by virtual disassembly and assembly of unit operation equipment, students were guided to carry out problem-oriented thinking and be the center of the learning process, while teachers played more roles in guiding and answering questions. On the other hand, teachers selected engineering cases with moderate difficulty and integrated them into the course, so as to improve students’ self-efficacy by the sense of achievement coming from project promotion. Curriculum politics elements of engineering cases were explored to integrate guidance on values into knowledge teaching and ability training, in response to the policy of rejuvenating the country through science and education. Process evaluation was strengthened by establishing a multi-level evaluation system combining classroom testing, equipment calculation and selection, literature research, group tasks, final exams, experiment and practice, project design and other aspects, focusing more on evaluating autonomous learning ability, innovative thinking and teamwork ability.

4.1.4 Operate

Cooperation mechanism was built. Based on the industry-college-research platform, college-enterprise joint cultivation projects, practical teaching bases and other foundation conditions, theoretical and practical teaching closely linked to the project life cycle were carried out. Talent cultivation was able to take innovative spirit and practical ability into account, keep up with industry needs and technological trends, and enhance students’ employment competitiveness and career sensitivity.

Guarantee mechanism was built. “Teacher-Engineer” teaching group was established with clear scope of guidance and collaboration. The “Engineer” referred to the application-oriented talents with experience in food industry. The teaching group combined the practical experience of food industry to jointly plan and complete teaching activities to ensure pertinence and prescription, realizing the idea of teaching and practice based on engineering projects.

Supervision mechanism was built. The review process of teaching syllabus ensured that the teaching content met the cultivation objectives and took academic and practical value into account. The process supervision was carried out through establishing an anonymous multi-dimensional evaluation system, which collected suggestions from all parties in a timely manner to continuously improve teaching and talent cultivation.

4.2 Constructing the Knowledge System

It was a comprehensive process to construct the knowledge system based on CDIO concept, which needed flexible design in combination with the colleges' discipline orientation and research expertise, industry-university-research platform, and experimental practical conditions, etc. As a typical unit operation equipment covering three transfer processes, the rectifying equipment was selected as the research object. Following the logic of “Conceive-Design-Implement-Operate”, the teaching content was organized in a problem-oriented perspective, and a stereoscopic and closely-connected knowledge system was constructed. The design project of rectifying equipment was a comprehensive application of "Three-transfer Theory", and the main parts of rectifying equipment included rectifying tower, reboiler, condenser, fluid conveying system, etc. Based on the design process of the rectifying equipment, the main knowledge architecture of the course was arranged, then the relevant knowledge of other commonly used unit operations was supplemented according to requirements. The example of constructing knowledge system is shown in Figure 2.

The “Conceive” stage mainly focused on the basic concepts and principles of food engineering principles, in order to lay a solid foundation for learning the detailed content of the course.

The “Design” stage was based on the design process of the rectifying equipment. The teaching was driven from the perspective of project promotion. The concepts, principles, calculation and design selection behind the main components such as the rectifying tower, heat exchanger and fluid conveying system were taught according to the design process. On this basis, knowledge about other typical unit operations was supplemented. Detail knowledge required to carry out equipment design was shown in Figure 3 to 6.

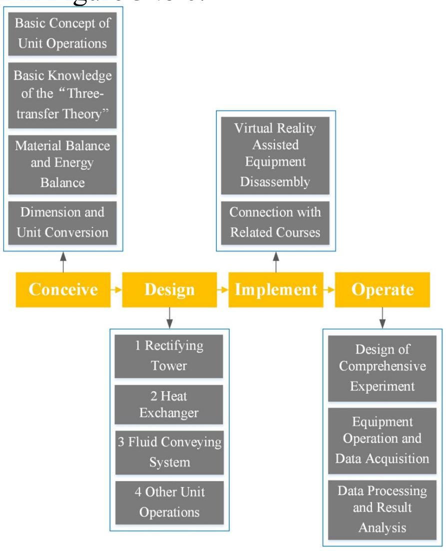

Figure 2. An Example of Knowledge System Construction

As shown in Figure 3, taking sieve plate tower as an example, the design process of rectifying tower mainly included designing scheme and process flow, analyzing material balance of the whole tower, calculating the plate number, clearing operating conditions of rectifying section, verifying gas-liquid load of rectifying section, design the size of process structure, checking fluid mechanics and plotting load performance diagram of rectifying section. The detail knowledge required to complete the above design was listed at the right side of the
Figure 3. For example, to design the scheme and process flow, students needed to have relevant knowledge of distillation and rectification principles, and the structure of gas-liquid mass transfer equipment. The reading method of Figure 4 to 6 is similar to Figure 3.

The "Implement" stage took advantage of technical methods like virtual disassembly and assembly, and contacted with relevant course knowledge, so as to help students to have a more comprehensive and intuitive view of the design process of unit operation equipment.

The "Operation" stage encouraged students to design comprehensive experiments. The equipment operation, data acquisition, data processing and result analysis were carried out in a teamwork manner, so that students could have a holistic understanding of the design, development, operation and maintenance of unit operation equipment, and construct the course knowledge cognition with the help of the whole life cycle of engineering projects.

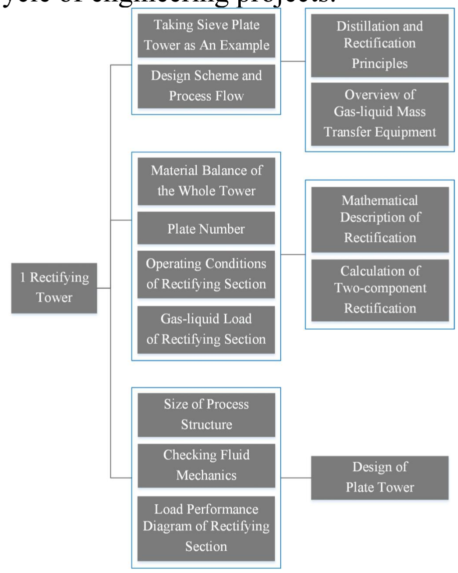

Figure 3. Detail Knowledge Required to Design the Rectifying Tower

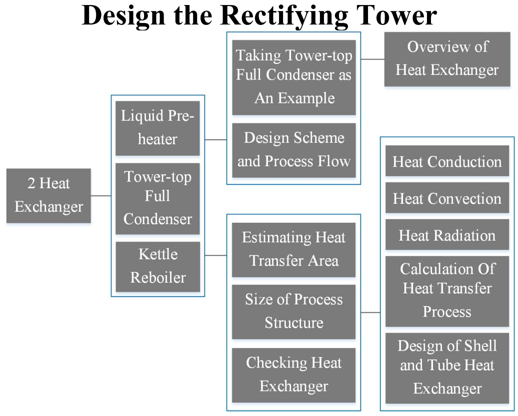

Figure 4. Detail Knowledge Required to Design the Heat Exchanger

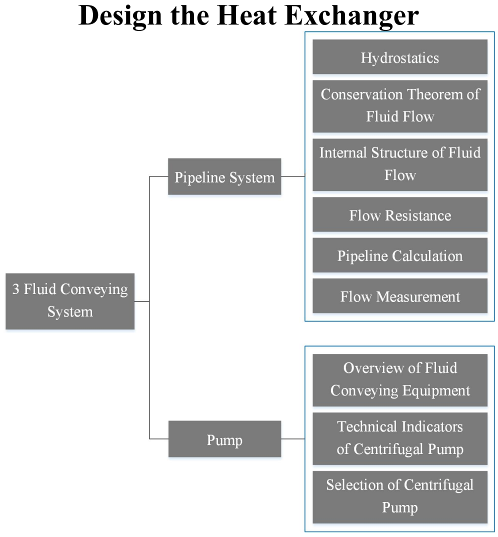

Figure 5. Detail Knowledge Required to Design the Fluid Conveying System

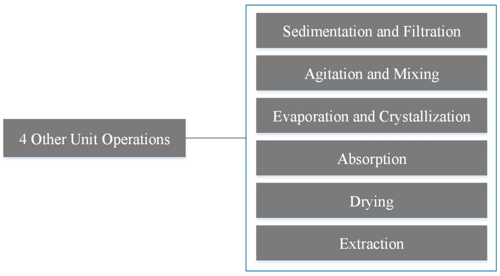

Figure 6. Detail Knowledge Required to Design Other Unit Operations

5. Summary

Based on CDIO concept, the teaching reform of "Food Engineering Principles" course was explored. The overall design of teaching process was combined with the practical experience of food industry. Students' initiative and participation can be enhanced by the project-driven teaching pattern, and the engineering practice ability is emphasized, which can help cultivate high-quality innovative and applied talents.

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