The Progressive Project-based Teaching Practice for Process Equipment and Control Engineering

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Abstract. In the context of the information age and engineering education, higher education is currently facing challenges and opportunities to transform from traditional to the-state-of-art teaching and learning methods. The development of new teaching and learning methods are of great significance for professional development and talent cultivation. Besides, the systematical integration of diverse teaching methods and learning approaches is a future development trend to effectively improve the education quality. The Process Equipment and Control engineering Department carried out an education project by integrating the progressive project teaching method with a non-linear learning approach. The project was achieved by constructing a ‘Design Recognition- Design Drawing- Design Mastery’ gradient learning framework for based on three applied practical courses, namely, ‘Process Equipment CAD’, ‘Professional Design’, and ‘Process Integrated Equipment’. Its application can comprehensively enhance students' abilities in process engineering system and equipment design through a progressive teaching and learning process that first recognition, followed by drawing, and finally mastering and application for related design plans, which in turn optimizes the overall development of the discipline and elevates the quality of talent cultivation.

Keywords: Progressive project teaching, Non-linear learning, Process Equipment and Control engineering, Course group

1 Introduction

The engineering education accreditation emphasizes that professional development should be ‘student-centered’ and guided by ‘student learning outcome’ [1, 2]. Based on this, a continuous and effective quality improvement mechanism should be established to promote the cultivation of high-quality engineering and technical talents. Faced with the new opportunities and challenges brought about by engineering education accreditation, the Process Equipment and Control Engineering major must continually explore new methods for undergraduate teaching and achieve compatibility and inclusivity for state-of-the-art teaching and learning method, which should align with its characteristics, stimulate students' independent learning, and emphasize learning outcomes simultaneously.

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The technology of process equipment is of utmost importance in the process industry, influencing sectors such as chemical engineering, energy, pharmaceuticals, food, and more, which directly impacts the overall comprehensive strength of a country [3, 4]. The major Process Equipment and Control Engineering, which combines inherent attributes of general education and features of multiple disciplines, is a comprehensive and highly practical major with process equipment as its core, and process principles and process control as its two wings. Based on the characteristics of the Process Equipment and Control Engineering major mentioned above, it is of significance to change the traditional indoctrination teaching method, and introduce a combined teaching method that close to engineering practice, to cope with the current informatization age and meet the demand for cultivating high-quality engineering and technical talents.

'Process Equipment CAD', 'Professional Design', and 'Process Integrated Equipment', serve as the three major practical and application-related courses in the major of Process Equipment and Control Engineering. These courses act as an important bridge for students to apply the theoretical knowledge and extend them into engineering practices. The three courses hold a crucial position within the entire curriculum system, and their teaching qualities of will directly impact the output talent quality for Process Equipment and Control Engineering major. Thus, the three courses can be serves as an excellent platform for the exploration of new teaching and learning methods. The study aims at forming a 'course group' with these three courses, implementing progressive project teaching method, integrating with non-linear learning method, thus constructing an innovative progressive project teaching and learning approach under the framework of 'Recognition-Drawing-Mastery'. The introduced approach not only strengthens the inherent connections for the knowledge within these courses, accelerates multidisciplinary integrated teaching, but also contribute to inspiring students' interest in independent learning and enhance the teaching quality and long-term talent development.

2 Theoretical foundation

Project-based teaching method aims to use engineering projects as the entry point for teaching and advances teaching process according to the project's development [5]. It decomposes an engineering project into several tasks, deeply incorporates theoretical knowledge into each task point, and uses these task points as the guiding force to inspire students' interest in learning and cultivate students' professional skills. It has the characteristics of theory-practice Integration teaching and task-driven independent learning. During the teaching process, instructors demonstrate the project appropriately, and then students collaborate on assigned tasks within a defined timeframe. Compared to traditional teaching activities, project-based learning poses higher demands on both teachers and students. Based on its definition and characteristics, the project-based teaching is a continuity and progressive teaching and learning activity that may need integration of multiple courses and more than one semester for implementation.

Nonlinear learning is based on the 'cognitive flexibility theory' and 'Random Access Instruction' of American scholar Spiro [6-8]. Spiro believes that (1) learners can form a complete and appropriate representation of new knowledge by combining it with previously acquired knowledge. (2) Instead of passively extracting previously learned knowledge verbatim from memory, learners need to engage in independent learning based on practice and context, integrating the knowledge they have acquired. The Nonlinear learning has four characteristics: (1) the non-systematic nature of learning content, (2) the fragmentary nature of learning time, (3) a drag-and-drop style of knowledge transfer, and (4) the active construction of knowledge. These characteristics also indicates that the Nonlinear learning is a comprehensive, holistic learning approach that requires more time and a greater accumulation of knowledge. By integrating nonlinear learning methods into university classrooms, it is expected to significantly improve the efficiency and effectiveness of students' knowledge acquisition. During nonlinear learning studying process, teachers are responsible for providing educational resources, tools, and corresponding instructions. Learners independently acquire the knowledge and methods they need by using the nonlinear learning method. They can acquire knowledge at convenient times and locations through various terminal devices such as personal computers and cellphones. After completing a series of courses, learners can enhance their knowledge levels. However, it should be mentioned that the nonliner learning method is entirely based on individual interests, and may not be suitable for all students. The goal-oriented nonliner learning method which provides a certain context for learning knowledge is more suitable for college classroom.

It is of great significance to integrate the teacher’s progressive project-based teaching method with students' nonlinear learning method. The progressive project-based teaching method stimulates students to develop learning interests by providing specific learning scenarios and project backgrounds. And through the progressively deepening projects, students experience the achievability of applying knowledge in a tangible way, which in turn help to establish a knowledge framework in practice and reinforce the knowledge learning process. The nonlinear learning with the characteristic of knowledge active construction can effectively promote the alignment of thinking logic and learning abilities. This paper proposes an innovative teaching approach that integrates the teacher’s progressive project-based teaching method with students' nonlinear learning method, aims at the comprehensive learning and practice of interdisciplinary integrated knowledge, strengthening professional practice development, and enhancing the quality of talent cultivation.

3 Implementation process

3.1 Progressive Project Teaching Approach

The progressive project teaching framework for Process Equipment and Control Engineering is illustrated in Figure 1. The implementing progressive projects teaching method has two goals. Firstly, based on engineering projects, the teachers should emphasize practical aspects, streamline teaching content, and reinforce the intrinsic connections between knowledge. Secondly, it promotes nonlinear learning from the student's perspective, facilitating a deep understanding, mastery, and integrated application of professional knowledge to solve engineering problems. This in turn achieves a profound integration of ‘teaching’ and ‘learning’, enhancing the quality of talent cultivation in Process Equipment and Control Engineering.

The classroom demonstration project for progressive project teaching is the Methanol Steam Reforming for Hydrogen Production project. The explanation and learning of this project span two semesters, integrated across three courses. In the second semester of the third year, the ‘Process Equipment CAD’ course introduces the principles, process design, and equipment design process of methanol steam reforming for hydrogen production. Using this project as a case study, the course covers the fundamentals of process equipment visualization, 2D drafting, and 3D drafting. In the first semester of the fourth year, the "Professional Design" course briefly explains the equipment design and verification process for methanol steam reforming for hydrogen production. Reference materials are provided, and students are grouped to design typical heat exchange equipment and tower equipment in conjunction with the engineering project. The "Process Integrated Equipment" course is then conducted, using methanol steam reforming for hydrogen production as a case study. It delves into the development of process processes and the knowledge related to integrated equipment design.

After the study of three courses mentioned above, students achieve a comprehensive understanding and mastery of process development and process equipment design. In the second semester of the fourth year, during the "Graduation Design" course, students collaborate in groups to carry out engineering projects such as the Acetic Acid Ethyl Ester project, reinforcing learning, applying and expanding relevant knowledge, and innovating in practice.

Progressive project-based teaching practice for Process Equipment and Control Engineering			
Goal	Integration of Teaching and Learning	• Emphasize engineering, emphasize practice; streamline instructional content, strengthen the inherent connections of knowledge. • Promoting students' nonlinear learning to enhance the quality of talent cultivation.	
Outline	Design Recognition →	Design Drawing →	Design Mastery
Project instruction	Methanol steam hydrogen production project		
Course group	Process Equipment CAD	Professional Design	Process Integrated Equipment
Content	Process Flow Diagram Process Flow Drawing, Equipment Layout Drawing, Piping Layout Drawing Process Equipment Diagram Assembly Drawing and Part Drawing	Heat Exchange Equipment Tower Equipment Other equipment	Process Development Design of Complete Sets of Equipment
Application	Acetic Ethyl Ester Project and so on（Graduation Project）		

Figure. 1 The progressive project teaching framework.

3.2 Progressive Project Teaching Method

3.2.1 Classroom Reform of "Process Equipment CAD", Promoting " Design Recognition-Design Drawing”

The course aims to teach students the methods, steps, and techniques for recognizing process industry drawings (process flow diagrams, equipment layout diagrams, piping layout diagrams), as well as process equipment assembly drawings and part drawings. In addition, students use both 2D and 3D design software to represent process equipment (as shown in Fig. 2), developing preliminary skills in using large-scale design software to solve engineering problems.

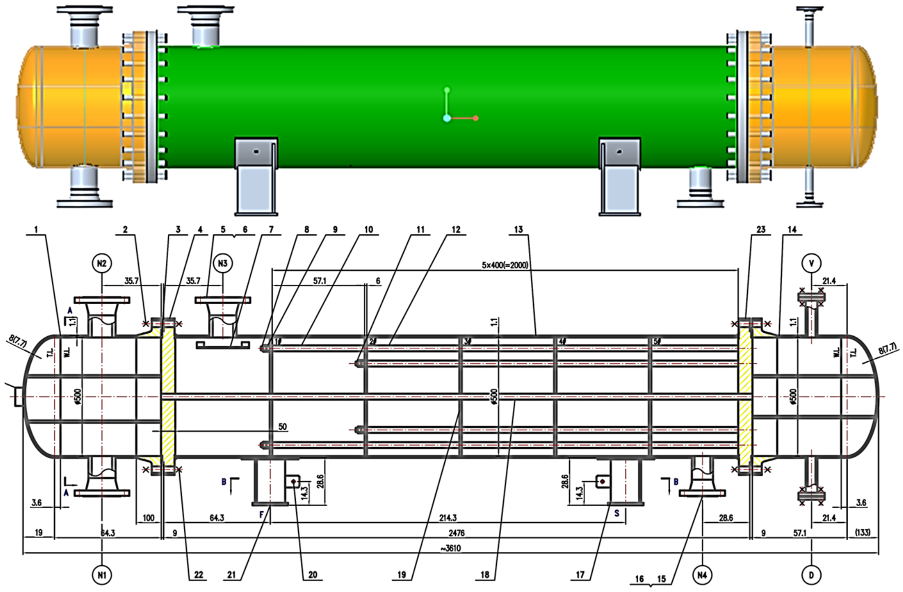

Figure. 2 2D and 3D drawings of heat exchange equipment.

Utilizing diverse teaching methods, the course integrates both in-class and out-of-class activities, forming a closed-loop system to promote studying. As shown in Fig. 3: (1)Pre-class Preview: Distributing PowerPoint slides and relevant learning materials, posing questions to encourage student reflection. (2)Classroom instruction: Using engineering projects as explanatory examples, adopting an interactive and equal teaching method, streamlining explanatory content, and reinforcing the inherent connections within the knowledge system. (3)Flipped Class: Focused computer sessions to complete 2D and 3D drawings of typical equipment. This leverages students' initiative for self-learning, collaborative progress sharing, group coordination on computers, teacher-student discussions, problem identification, and explanations (student-led, teacher-assisted). (4)Face-to-face communication: Encouraging students to ask questions outside of class and actively answering them. The teacher summarizes typical questions for in-class explanation. (5)Discussion board: Group drawing sessions, offline group discussions for mutual assistance, consolidating learning, and improving efficiency. Through diverse teaching methods, students' abilities to ‘Design Recognize-Design Drawing’ can be effectively developed.

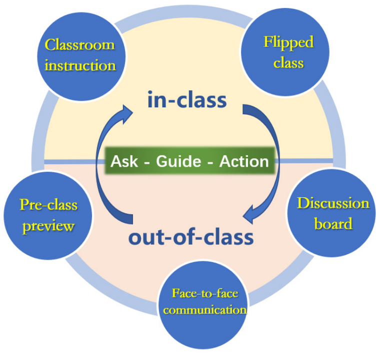

Figure. 3 A diversified teaching approach that combines in-class and out-of-class activities.

3.2.2 Project-based teaching in 'Professional Design', promoting 'Design Drawing- Design Mastery'.

Through the learning of the 'Process Equipment CAD' course, students have already grasped the basic structure of typical equipment and can use both 2D and 3D software to draw these typical Equipment. Based on this, the 'Professional Design' course is conducted in groups, spanning one month. Its goal is to guide students in independently designing specific sections of the process industry and related equipment structures. As shown in Fig. 4, the content of 'Professional Design' is selecting the distillation section of an industrial site as the design object and conducting design in three directions: flow design, structural design, and control system design.

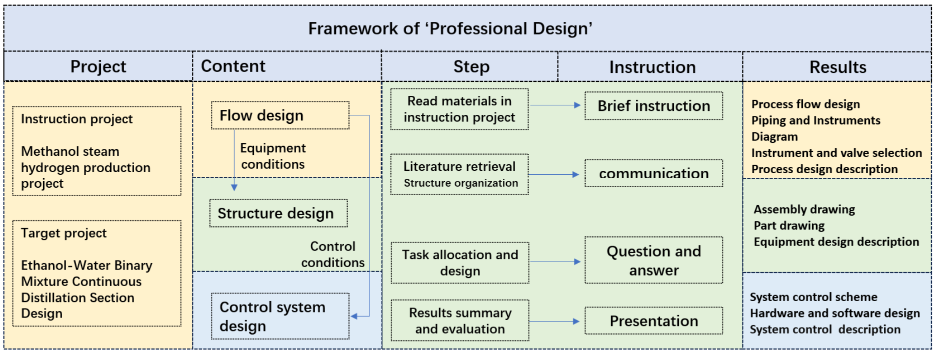

Figure. 4 Professional design framework diagram.

At this stage, students lack independent experience in engineering design. To better integrate theoretical knowledge and engineering practice, the course provides detailed information on the 'Methanol Steam Reforming for Hydrogen Production project' as a reference for independent study. It also uses a new process industry and section as the design object. This course setup offers similar but not identical project materials, brief explanations, design ideas, and encourages students to engage in independent thinking and analysis, sparking their interest in autonomous nonlinear learning. Taking the example of the structural design of the ethanol-water binary mixture continuous distillation section, it includes equipment structure design for the feed preheater, distillation column, reboiler, condenser, and storage tank. Through the structural design and verification of these equipment, students enhance their understanding of the principles related to equipment design, strengthen their practical drafting skills, and cultivate their ability to collaborate in teams to solve engineering problems. Through project-based teaching, students progressively deepen their learning and application of drafting methods and techniques based on their recognition of drawings, facilitating a natural transition between 'Design Drawing-Design Mastery'.

3.2.3 Process Integrated Equipment: Strengthening knowledge connections, promote' Design Mastery'

'Process Integrated Equipment' is a comprehensive professional course for the Process Equipment and Control Engineering major. The content of this course includes aspects such as process development, process design, unit equipment design, pipeline design, control component design, insulation design, and corrosion protection design. It integrates the full set of technologies involved in process equipment design. This course enables students to master the integrated technology of process equipment, providing knowledge reserves for students in this major to undertake technical work at various stages of process industrial production after employment.

After students have studied and practiced the relevant technologies in engineering practical projects through 'Process Equipment CAD' and 'Professional Design,' they already have a certain understanding of the framework for process industrial design. Then, the course 'Process Integrated Equipment' plays a crucial role in building the inherent connections between knowledge. As 'Process Integrated Equipment' encompasses numerous knowledge points and a complex knowledge system. To strengthen the inherent connections within the knowledge system, 'Process Equipment CAD' simplifies the content related to pipeline design and equipment control in the course, focuses on engineering examples, and reinforces the organic connections between process development, process design, equipment design, insulation design, and corrosion protection design. This effectively promotes the cultivation of students' in-depth understanding of 'Knowledge Mapping' in the field of process industries.

3.3 Student Nonlinear Learning Methods

German educationalist Goethe once said, 'Predicting results or solutions to students will hinder their efforts to study; therefore, conclusions should be delayed. Student mistakes should not be overly emphasized. Teachers must understand that all vibrant ideas have a slow development process.' College education should encourage students to integrate their own interests, independently choose tasks, revise methods, engage in autonomous nonlinear learning, and independently improve and innovate, placing less emphasis on results and more on the process, aiming for goals.

The progressive project-based teaching practice has streamlined the teaching content, diversified teaching methods, emphasized the progressive learning and inherent connections of knowledge, strengthened the practical application of theoretical knowledge, and organically unified with Spiro's theory of cognitive flexibility and the idea of random access teaching. It provides a driving force, direction, and method for students' nonlinear learning, thus promotes the students' Nonlinear Learning. Furthermore, this approach fully combines autonomous learning, collaborative learning, and research-based learning, allowing students to become masters of their learning. This in turn fosters more outstanding talents with innovative spirit, practical capabilities, and comprehensive qualities.

3.4 Expansion of Progressive Project-Based Teaching in the Graduation Design

The 'Graduation Design' is a comprehensive practical teaching approach that combines learning, practice, exploration, and innovation [2]. The 'Graduation Design' is an extension and application of the course-group progressive project teaching practice. Through progressive project teaching practice, students integrate theory and practice, apply their acquired professional abilities and skills, develop a comprehensive understanding of engineering projects, and master methods and approaches for independently solving complex engineering problems. Building upon the foundation of progressive teaching practice, the 'Graduation Design' phase encourages students to shift their design topics from assignment-oriented to engineering project-oriented, increasing the proportion of engineering and innovative project designs. This approach enhances the continuity and practicality of production-oriented graduation designs, ultimately improving the overall competence and professional skills of graduates in this field.

4 Conclusions

Based on the framework of course groups, the combination of progressive project-based teaching and nonlinear learning provides a soul and vitality for teacher-led progressive project-based teaching and sets framework and principles for student-led nonlinear learning. By integrating three courses (‘Process Equipment CAD’, ‘Professional Design’, and ‘Process Integrated Equipment’), it achieves a layered and interconnected progression of course content, promoting a progressive learning approach of ‘Design Recognition- Design Drawing- Design Mastery'. The approach helps students understand the knowledge framework and strengthen engineering practical skills while reduces the learning intensity for students on one hand, and enhances students' ability in process equipment design and consequently improve the quality of professional talent cultivation. It is also appliable for other engineering majors to reinforce the combination of theory and practice.

5 Citing related work

This section gives examples of citations of the journals [1, 5, 6], conferences [2], books [3, 4, 7, 8] to illustrate how they appear in the main text section.

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