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Exploration of Teaching Reform of Digital Circuit Course Based on CDIO Engineering Education Mode Under the Background of Emerging Engineering Education

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Abstract: The construction of emerging engineering education requires Chinese colleges and universities to cultivate innovative and outstanding engineering talents to cope with the new technological revolution and industrial revolution. Computer major is one of the most closely related and potential majors with the emerging engineering education. As the core basic course of hardware courses for computer major, Digital Circuit has strong advanced nature and engineering attributes, so it has become the vanguard of teaching reform under the background of emerging engineering education. Based on the current teaching situation of Digital Circuit, this paper analyzes the main problems and causes in the teaching process, and proposes to introduce the CDIO (Conceive-Design-Implement-Operate) engineering education concept into the teaching of Digital Circuit in combination with the construction goal of emerging engineering education. Reform should be carried out from the aspects of reconstructing teaching ideas, designing teaching systems, and implementing project-driven teaching methods. In the reformed teaching mode, teachers change from lecturers to guides, who guide students to study and discuss, and students from passive recipients to active learners, who study actively by themselves. In the learning process, students' abilities of self-learning, teamwork, engineering practice and innovation and entrepreneurship etc., which the excellent engineering talents need to have, can be exercised and improved significantly.

Keywords: Emerging Engineering Education, Digital Circuit, CDIO, Teaching Reform

1. Introduction

In order to cope with the new technological revolution and industrial revolution, support the rapid development of the new economy, and cultivate engineering innovative talents, the Ministry of Education proposed emerging engineering education construction strategy. Since the emerging engineering education construction plan was formally proposed in 2017, a series of guiding documents have been formed, including the Fudan Consensus on the Emerging Engineering Education Construction [1], the Action Line on the Emerging Engineering Education Construction [2] and the Guidelines for the Emerging Engineering Education Construction [3], a series of emerging engineering education research and practical projects have been carried out, including the "Construction of a Demonstration Microelectronics College" "New Engineering Demonstration Modern Industry College". This not only points out the direction for the emerging engineering education construction, but also accumulates experience for the overall layout and implementation path of the emerging engineering education construction.

Internet information technology, artificial intelligence, big

data, intelligent manufacturing and new materials constitute the main elements of the emerging engineering construction. Computer major, which is the most closely related and potential majors with the emerging engineering education, has become the vanguard of the emerging engineering education [4]. At the same time, the new round of information revolution and social transformation put forward new goals for engineering education of computer major. Therefore, computer majors should grasp the opportunity of training new engineering talents, creating new and excellent emerging engineering, providing new impetus for national development, and cultivating a large number of diversified, innovative and excellent engineering talents.

In order to adapt to the emerging engineering education construction and engineering education mode, the curriculum construction and teaching reform of computer major have become the focus of relevant higher educators. Jiang Zongli proposed that to realize the reform of computer major under the background of emerging engineering education construction, it is necessary to update the basic educational concept, strengthen industry-university cooperation, and realize incremental optimization, stock adjustment and cross-integration [5]. Li Cuiping et al. explored a new data-centered curriculum system for computer majors that adapt to the development of the times and industrial needs to promote the emerging engineering education construction [6]. He Qinming et al. pointed out that in terms of curriculum construction, it is necessary to strengthen the construction of computer general courses and cross-curricular courses, strengthen the reform of teaching methods, and pay attention to the cultivation of students' computational thinking ability and new technology application ability [7]. Peng Yanfei et al. proposed to reform the practical teaching link should be reformed into the diversified training mode of "diversifying across grades according to the students' needs" [8].

Digital Circuit is the core basic course of hardware courses for computer major, which plays a connecting role in the curriculum system. The logical relationship diagram of the courses is shown in Figure 1. With the rapid development of the design and manufacturing technology of large-scale integrated circuits, the applications of various intelligent controls and embedded systems are emerging in endlessly. The traditional teaching mode and content can no longer meet the training needs of high-quality engineering talents, and cannot adapt to the development trend of Emerging Engineering construction. Therefore, it has become an urgent concern for computer teachers in Colleges and universities to deeply analyze the main problems faced by curriculum teaching and explore the teaching reform of Digital Circuit curriculum under the background of Emerging Engineering Construction.

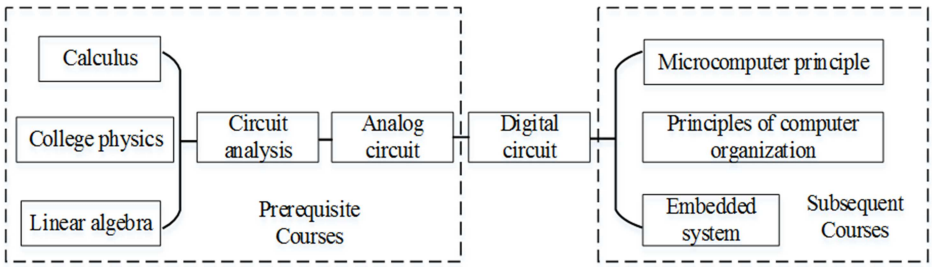

Figure 1. *Logic diagram of Digital Circuit course.*

This paper will introduce the classical CDIO engineering education concept into the teaching reform of Digital Circuit course. After analyzing the main problems and causes existing in the traditional teaching of Digital Circuit, aiming at engineering application, the teaching reform is carried out from multiple levels and aspects, such as teaching concept, teaching system and teaching methods, in order to explore a new teaching mode of hardware courses of computer major under the background of emerging engineering education, which can improve students' ability to adapt to changes, teamwork and engineering practice. And finally lay the foundation for application-oriented colleges and universities to cultivate application-oriented talents with strong engineering literacy.

2. CDIO Engineering Education Concept

CDIO engineering education concept is an engineering education concept founded by four universities including Massachusetts Institute of Technology and Royal Swedish Institute of Technology after four years of exploration and research. It aims to cultivate applied talents, provides students with an engineering education environment based on the product development cycle, which integrates four stages: conception, design, implementation and operation, and allows students to learn engineering in the way of active practice and organic connection between courses [9].

It is of far-reaching significance to promote the CDIO engineering education concept in the context of emerging engineering education construction. For individual students, they can make full use of the university's complete disciplines and rich learning materials, approach the engineering practice as much as possible, and participate in the whole process from engineering conception, design, implementation to operation [10]. In the learning process, students will not only master the basic subject knowledge, but also exercise the engineering practice ability, so as to obtain the cultivation of all-round comprehensive ability. For social development, a group of outstanding engineering and technological talents can be cultivated to serve the national strategy and meet industrial needs.

The Digital Circuit course not only has high theoretical nature, but also has strong engineering practicality, which is more necessary to cultivate students' engineering consciousness and innovation consciousness. Therefore, students should not only have a solid grasp of basic theories and concepts, but also have the ability to analyze and design digital circuits [11]. Combining the CDIO engineering education concept with the Digital Circuit course, the teaching content can be first disassembled into projects that are closely related to the reality of life, and then the project theme, difficult points, key technologies, and project collaboration scenarios can be integrated into the teaching content. Finally, the project design and implementation is used as an intermediary to run through the teaching process to cultivate students' ability of self-learning, independent thinking, communication and cooperation, and other engineering literacy [12].

3. Main Problems in Traditional Teaching of Digital Circuit

3.1. The Teaching Form Is Conservative, the Teaching Method Is Rigid

The teaching mode of Digital Circuits is still based on traditional multimedia teaching. Teachers instill in the classroom, students passively accept knowledge. For students, there is no space for independent thinking, exploration and innovation, so that students are lack of enthusiasm, initiative and innovation.

3.2. The Curriculum Arrangement Is Improper, the Teaching Efficiency Is Low

There is a problem of the separation of time and space between theoretical and practical teaching in the course arrangement of Digital Circuits. That is to say, the theoretical knowledge is first taught in the classroom, and then the verification experiments are carried out in the laboratory. The theory and practice are separated from each other, and they cannot be smoothly connected in time and space, resulting in low overall teaching efficiency and poor teaching effect.

3.3. The Teaching Content Is Isolated, the Course Update Is Not Timely

In the traditional teaching of Digital Circuit, the teaching content is separated from the actual engineering application. In the course of teaching, we only pay attention to the teaching of specific knowledge points, and do not map theoretical knowledge to practical engineering problems, which makes students detached from the engineering application background, and their engineering literacy is generally low. For example, most theoretical courses only teach the functions and characteristics of flip-flops, and do not expand and explain how flip-flops are applied to actual circuits. In addition, Digital Circuit is a more traditional course, and the content is still the theoretical knowledge of more than ten years ago. At present, the current digital circuits are dominated by large-scale and big data integrated circuits. If the curriculum is not updated in time, it will be difficult for teaching development to keep pace with the times [13].

3.4. The Assessment Form Is Single, the Evaluation Method Is Lack of Diversity

The assessment form of the course is generally a paper test, and the final score is composed of the paper score and the usual score in a certain proportion. This single assessment and evaluation method lacks the supervision of students in the learning process, pays less attention to implicit ability and engineering literacy, and the assessment results cannot fully reflect students' comprehensive practical ability and innovation ability. The examination method that emphasizes results and ignores process not only rigidizes students' thinking ability, but also hinders students' learning initiative and enthusiasm, so that students' ability of mutual communication and spirit of unity and cooperation cannot be effectively exerted, and it is difficult to adapt to the development needs of the future society [14].

Therefore, in order to solve the problems existing in the current Digital Circuit course and explore the teaching mode of the computer major hardware courses under the background of emerging engineering education, this paper introduces the CDIO engineering education concept into the teaching reform of Digital Circuit, and carries out the teaching reform from multiple levels and aspects, such as teaching concept, teaching system and teaching method, based on theoretical training and aiming at engineering application.

4. Teaching Reform Measures Based on CDIO Mode

4.1. Reconstruct the Teaching Concept Under CDIO Mode

According to the CDIO outline, engineering education should cultivate students' good teamwork spirit and ability to solve engineering problems, including system analysis and practical ability, on the basis of teaching students' professional technical knowledge and basic skills, so as to meet the development needs of modern engineering teams, new products and new systems [15]. The teaching should be organized with the engineering concept of practical application, so that students can complete the engineering projects systematically in turn according to the "conceive-design-implement-operate" product life cycle, and "learn" in the whole process of the complete engineering project.

After clarifying the CDIO teaching concept, we can ensure that the teaching concept can run through the whole teaching process from three dimensions as follows.

4.1.1. Institutional Guarantee

The syllabus of Digital Circuit needs to be adjusted and modified. The theoretical and practical teaching contents that

are more in line with the needs of technological development and social skills need to be formulated and the setting of subject projects, experimental projects, comprehensive course training projects based on CDIO need to be clarified.

4.1.2. Implementation Guarantee

Students are required to participate in the whole process of project development, and to achieve an all-round integration of teaching, learning and doing in the process, so as to improve students' comprehensive ability. At the same time, teachers rely on scientific research teams, experimental platforms and other resources to achieve professional education and engineering practice education for students, and use words and deeds in the teaching process to improve students' ideological and political consciousness [16].

4.1.3. Assessment Guarantee

Diversified teaching assessment methods should be formulated and comprehensively score with the method of combining process evaluation and summary evaluation is used to strengthen the monitoring of the whole teaching process. The assessment content is divided into several modules, such as classroom participation, after-school homework, mid-term test, experimental operation (including simulation experiment and hardware experiment), CDIO projects, final exam, etc. Among them, in the traditional paper-based examination, we should appropriately add design questions to examine students' innovative ability. Classroom participation and homework can reflect the timely learning effect; experimental operation can test students' practical hands-on ability, the ability to discover and solve problems. Students' teamwork ability and engineering practice ability can be tested by completing CDIO projects in groups. The reference assessment standards of the Digital Circuit are shown in Table 1.

Table 1. *The reference assessment standards of Digital Circuit.*

Evaluation type	Process evaluation				Summary evaluation
Assessment links and proportion	Classroom participation (10%)	Homework Mid-term test, (10%)	Experimental operation (10%)	CDIO projects (20%)	Final exam (50%)
Assessed ability	Learning methods; learning habits	Understanding and mastering theoretical knowledge	Hands on operation ability; problem discovering and solving ability	Engineering practice ability; Teamwork ability	Mastery of knowledge system Knowledge application ability Psychological quality
Scoring source	Rated by teachers	Peer-assessment Rated by teachers	Peer-assessment Rated by teachers	self-assessment Peer-assessment Rated by teachers	Rated by teachers

4.2. Reconstruct the Teaching Concept Under CDIO Mode

According to the connotation requirements of the emerging engineering education construction [17], the teaching reform of Digital Circuit should follow the latest development of the industry and technology, and introduce the latest requirements of the industry for talent training into the teaching process to cultivate future diversification, innovative and outstanding engineering talents. The basic structure of knowledge that guided by talent training objectives is constructed, and a teaching system that conforms to the CDIO mode is designed. Specific implementation measures include the following aspects:

4.2.1. Update the Teaching Content, Perfect the Knowledge System

The latest scientific and technological achievements should be added such as large-scale integrated circuit design, electronic circuit design and embedded system to the teaching content to guide students to understand the frontier fields of the discipline. At the same time, the theory course is mapped to the engineering application, in which theory guiding practice, to make the concept is clearer and the knowledge is more systematic. Stimulate students' thinking through teaching content, and mobilize students' subjective initiative in learning so that students voluntarily invest more time and energy outside class.

4.2.2. Allow Computers to Be Brought into the Classroom, Link Theoretical Knowledge with Practical Operations

When teachers teach theoretical knowledge in class, they can set up some practical operation links, allowing students to use computer’s simulation software to realize circuit building simulation, where the node action and logical calculation process of various circuits can be seen in real time, so as to deepen their understanding of knowledge points.

4.2.3. Take Advantage of High-Quality Online Teaching Resources, Develop Innovative Media Learning Methods

Teachers can put their recorded teaching content or high-quality online teaching resources on the online learning platform, so that students can carry out personalized learning anytime and anywhere, and communicate with teachers in real time. This method changes the previous single classroom teacher teaching mode, not only enhances the students' learning initiative, but also returns valuable classroom communication time to students to show their CDIO projects as the owner of the classroom.

4.3. Implement Teaching Methods Under CDIO Mode

As mentioned above, CDIO mode cultivates innovative talents suitable for engineering development by providing students with an engineering education environment based

on the product development cycle. Therefore, the project-driven teaching method reform is implemented, which introduce the engineering projects in real life into the teaching of Digital Circuit and integrate the teaching content and knowledge points into the real environment of engineering projects. The reference CDIO projects design under the Digital Circuit course is shown in Table 2. The projects cover all the teaching contents from easy to difficult, from simple to comprehensive.

Table 2. *The reference CDIO projects design under the Digital Circuit course.*

CDIO projects	Relevant teaching knowledge points
Traffic signal control circuit	Design of combinational logic circuit
Festive cyclic lights	Counter, timer
tail lamp control circuit	Decoder, counter
Digital clock	Module-N counter, display decoder
Stair touch light	Principle and application of 555 timer
Hospital call system	Priority encoder, display decoding circuit
Electronic code lock	Decoder, latch, data selector, counter

Table 3. *Project-driven teaching method based on CDIO.*

CDIO process	Main content	Teachers' tasks	The ability that students need to achieve
Conceiving	Establish contacts and design projects	Disrupt the order of teaching materials & reorganize projects; Inspire students to establish the connection between curriculum knowledge and engineering application	Ability to integrate theory with practice, engineering literacy
Designing	Analyze tasks and disassemble items	Guide students to divide the project into several tasks; Sort out the task requirements of each part	Ability to analyze problems & logical thinking
Implementing	Team work to realize the project	Explain the key and difficult knowledge involved in the task; Guide students to analyze problems and solve problems independently	Practical operation ability, autonomous learning ability, team cooperation ability
Operating	Achievement display and evaluation project	Make comments on the completion of the project; Guide students to reflect and innovate	Language expression ability, writing summary ability, innovation &development ability

Students participate in the whole process of project development in the form of a project team, and complete project conception, design, implementation and operation one by one. First, according to the project tasks and specific requirements, the problems are disassembled and contacted to the related knowledge points of the course. Then the theoretical knowledge is learnt spontaneously and the circuit design is completed in the form of teamwork. Next, the problems encountered in the process of practical operation to make a real circuit are solved in time, and finally the project results are displayed by the team, the knowledge points used in the project are summarized and the problems and solutions encountered in the process are reflected on and sublimated. The implementation process of the project-driven teaching method based on CDIO is shown in Table 3.

The project-driven teaching method takes students as the main body and teachers as the facilitator, which changes the learning environment of the engineering classroom, realizes the whole process of theory and practice, in which let students participate in an all-round and deep way in the form of team cooperation. This kind of teaching method, which is based on students' development and meets the requirements of the development of the information society, effectively improves students' enthusiasm, learning effect, communication and cooperation ability and innovation ability, stimulates students' subjective initiative and expands students' vision. It is of great benefit to Individual student development, laboratory construction, professional planning and school development.

5. Conclusion

Under the background of the emerging engineering education construction, this paper takes the cultivation of innovative and excellent engineering scientific and technological talents as the general program, aiming at the teaching problems existing in the hardware course Digital Circuit of computer major, introduces the CDIO engineering education concept into the teaching reform, and proposes to reform from the aspects of reconstructing the teaching concept under CDIO mode, designing the teaching system under CDIO mode, and implementing the project driven teaching method under CDIO mode. In the reformed teaching mode, teachers are changed from lecturers to guides, who guide students to study and discuss, and students from passive recipients to active learners, who study actively by themselves. In the learning process, students' abilities of self-learning, teamwork, engineering practice and innovation and entrepreneurship etc., which the excellent engineering talents need to have, can be exercised and improved significantly.

The successful application of CDIO engineering education concept in the teaching reform of Digital Circuit course inspires us to refer to this method in the follow-up teaching reform in other hardware courses of computer major to establish the cross integration of multiple courses, and finally create a high-quality hardware courses platform of computer major under the background of the construction of emerging engineering education, which can cultivate more innovative and excellent engineering talents.

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