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The Practical Reform in Basic Courses under the Educational Philosophy of CDIO-the Course of "Digital Circuits and Logic Design" as an Example

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Abstract: ***In order to promote the curriculum reform of our university and further expand the digital informatization in higher education, this paper targets several teaching reforming issues in the electronic information discipline of our university. Guided by the CDIO-OBE teaching philosophy, multifaceted teaching strategies are proposed for the major, such as overall planning of talent cultivation, teaching methods of teachers, and advanced evaluations of core basic courses. Starting from the compulsory course of 'Digital Circuits and Logic Design', the top-down implementation of practical reforms and the effects of updating teaching team, and continuously improvement on setting experiments are analyzed. Based on the feedback from students' survey, it is confirmed as well that only through the effective integrations of digital technology and the higher-level blended teaching methods, and continuously optimized experiment reforms together can fundamentally promote the discipline construction and talent cultivation in the major of electronic information. Furthermore, through the closed-loop feedback of quantitative data from students' questionnaires, the practical reforms facilitate the digitization transformation of basic courses in our university.***

Keywords: Electronic Information Discipline, CDIO philosophy, Core basic course, Blended learning, Teaching reform**.**

1. Introduction

Since General Secretary Xi Jinping has put forward the overall requirement of "accelerating the modernization of education and running education that satisfies the people" in 2020, that emphasized the need for to promote informatization in higher education, continuously updating educational concepts, the reform of teaching modes, and system reconstruction [1]. Our university has always adhered to the educational policies, and developed moral education for students as a new generation of electronic information technology according to the national planning and industry needs in the southwestern region. We have set up corresponding professional and curriculum systems with the goal of cultivating applied engineering talents. Among them, the course "Digital Circuits and Logic Design" is not only the core basic course for undergraduate of majors such as electronic information, communication, computer science and automation, but also one of the postgraduate entrance examination courses for engineering students.

With the rapid development of information technology in the new era, contemporary university students have become Internet natives, who are used to accept new information technology services, gain knowledge and understand the world through various information technology carriers. Therefore, various forms of network information and digital media technologies have become important influencing factors for student to learn knowledge, that have also become a new playground for higher education. For example, online learning and blended learning have assisted in achieving wider coverage of educational ranges, allowing students from anywhere to enjoy high-quality course resources. Especially during the pandemic, various educational cloud platforms enabled teachers and students online at the same time, making educational resources more extensive and equitable. In addition, visualization tools, AR/VR collaborative learning, and other functions are assisting in precise teaching, and improving the quality of education continuously. Furthermore, using big data analysis technology, teachers can track the entire teaching process, examine students' weaknesses in learning or reflect their shortcomings in teaching, and propose targeted solutions to achieving effective learning. Therefore, the blended teaching with digital technology is said to promote educational equity to a large extent, comprehensively improving the quality of higher education, and gradually realizing the ideal of "teaching without class and teaching according to students' aptitude [2]."

Therefore, guided by the CDIO-OBE teaching philosophy [3][4][5], "Digital Circuits and Logic Design" (DCLD for short) taken as the starting point, the reform of course objectives will end with evaluating students' abilities of completing complex engineering solutions. Only in this way can we explore teaching practices from new perspectives, build course groups through integrating basic courses with advanced educational technology, and lay a solid foundation for the futural digital innovation of higher education.

2. Research Problems within Current Curriculums

According to the learning concept of CDIO (Conceive, Design, Implement, and Operate) for undergraduates of electronic information engineering, the basic course group includes not only fundamental courses such as "Advanced Mathematics", "Linear Algebra", "University Physics", but also discipline-based courses like "Fundamentals of Circuit Analysis", "Analog Electronics Technology", "Digital Circuits and Logic Design", and subsequent important specialized courses such as "Microprocessors and Microcomputer Systems", "Communication Electronic Circuits", "Signals and Systems", and "Modern Communication Principles". Among these, "Fundamentals of Circuit Analysis" and "Analog Electronics Technology" make up the foundation for "Digital Circuits and Logic Design", while this course serves as a prerequisite for "Microprocessors and Microcomputer Systems" and "Communication Electronic Circuits". Therefore, this paper took this course as an example, and the main challenges during the process of teaching reform practices were sorted out as follows.

- Problem 1: Lack of positioning course clearly in developing students' graduation competencies.

Previously, the DCLD course was categorized as a general platform course for engineering majors, following the unified teaching standards of the university. However, the teaching team did not differentiate the cultivation objectives of different majors and talents, nor did they analyze the course's strengths and its specific orientation towards developing students' graduation competencies. Thus, if this course is lack of strategic planning in talent cultivation and coordinated positioning within course groups, it would be hard to allocate different teaching teams according to distinct professional demands and knowledge systems. This inability would hinder the reconstruction of distinctive professional course groups and the formation of an integrated teaching system encompassing knowledge, skills, and qualities [3][4]. This is the first primary challenge in the course reform.

- Problem 2: Lack of resource sharing and coordination between courses.

Currently, there are often issues with the content and structure of course group for one major, such as weak overall planning, overlapping course objectives, or insufficient coherence in integrated content. For instance, the teaching objectives of DCLD should be guided by the CDIO-OBE teaching philosophy while align with industry demands. It requires not only to be correlated with the graduation requirements from industry, but also to linked with corresponding knowledge points across courses, and experimental projects of other relevant courses such as "Computer Systems", "Microprocessors and Microcomputer Systems", and "Communication Electronic Circuits". The collective discussion, resource sharing and coordination among courses are necessary to meet the needs of advancing talent cultivation and professional innovation. Such issue should be a key part of an integrated reform in educational system.

- Problem 3: Lack of flexible teaching methods for faculties.

Currently, over 90% of the engineering teachers in our university are non-education graduates. Although there are many PhDs within the teaching faculties, the primary advantage of engineering doctorates lies in their professional technical knowledge and research capabilities, rather than their educational experiences. Consequently, lacking of foundational knowledge in education and psychology, hinders them to translate their subject expertise into understandable knowledge for students. Sometimes, many young faculties found themselves unable to effectively convey their understanding, due to inadequate teaching skills. Additionally, their understanding of classroom teaching remains superficial, leading to low student engagement or poor teaching evaluations. Despite pre-job trainings are organized for teachers, inadequate practical classroom teaching experience and teaching strategies are still the challenges for young faculty members. Thus, there is a genuine need to enhance the teaching methods of some young faculty members in their classroom practices.

- Problem 4: Lack of an evaluation system from students' feedback.

Since the educational philosophy of our university is advocated as OBE (Outcome-Based Education), which focuses on outcome-oriented of a majority of students. Implementation of student-centered teaching and long-term data accumulation of students' feedback are required to thorough evaluation analysis to the DCLD course. Thus, utilizing bottom-up evaluation and students' feedback to optimize the curriculum system is essential for establishing a comprehensive, long-lasting, and continuously improvement to the reform.

3. The Reform Program of Teaching Practice

Therefore, we have carefully studied the mentioned points, and started practices from the DCLD course under the teaching philosophy of CDIO-OBE. We have adopted a top-down approach, beginning with the talent cultivation plan of our major. This process is illustrated in Figure 1 below, including the teaching system's program, course objectives, teaching content, instructor delivery, and student evaluation:

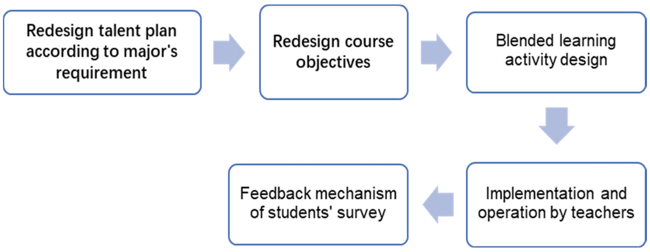

Figure 1: Flow of curriculum reform

Based on the talent cultivation plan for specific major, and outcome objectives, we have identified the learning and teaching objectives of DCLD within the curriculum group and determined how these objectives support the requirements for graduates. Then the teaching syllabus for this course were revised and tailored to different majors. To facilitate better teaching quality, four course objectives and three competency achievements are established for DCLD, and corresponding evaluation criteria for goal attainment is devised. Additionally, guided by the CDIO philosophy, we have integrated various course knowledge points with FPGA experimental projects to enhance students' comprehensive abilities. This systematic training involves digital system conceptualization, design, implementation, and operation throughout the entire teaching phase.

The teaching process adopted a blended learning approach, combining online and offline methods. We leveraged information technology platforms and vital resources in laboratories to promote practical methods, fostering students' capabilities of innovation and balanced development [8]. For example, online courses and micro-teaching are provided for students before class. During experiments, real-time monitoring and guidance are provided by teachers in classroom, who will make varying programming requirements for students in different majors. Following experimental sessions, e-reports submitted online are promptly graded and answered by teachers. Through submission of assignments including post-class reports and end-of-semester surveys, students can provide continuous feedback, that reflect their autonomy and innovation consciousness.

In the context of deep integration of information technology with educational experiences, the entire teaching team for DCLD within our university should be engaged in mutual learning, delivering the theory and practice to undergraduates in a balanced approach. Only by strengthening their understanding of educational theories, can teachers actively incorporate changes into their teaching practices, achieving satisfactory classroom outcomes for both students and teachers.

4. Implementation of Blended Teaching in the Programme

Taking the "Digital Circuits and Logic Design" course as an example, several important stages of student-centered blended learning are implemented as follows to improve the effectiveness of teaching reforms:

4.1 Pre-class Online Guidance:

By uploading pre-class materials and questions to the online platform's resource library for students, teachers encouraged students to watch inspiring videos on important topics and interesting project examples in advance. For instance, students majoring in integrated circuits not only diligently completed the pre-assigned questions, but also actively discussed professional knowledge issues on the platform with classmates, such as circuits related to AND or OR arrays, as shown in Figure 2 below. The guidance session enabled them to discover and solve questions during self-study and focused on how to enhance their self-learning abilities and sense of achievement.

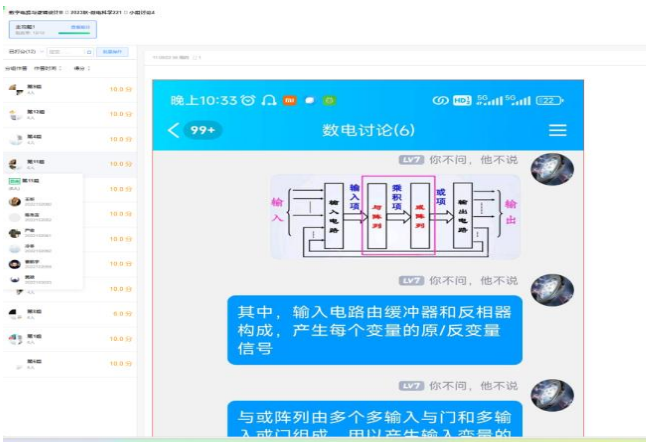

Figure 2: Group discussions on the platform of "rain classroom"

4.2 Seminar-style Teaching in Class:

Based on the specific teaching content for each major, teachers organized seminar-style teaching sessions into learning teams in classroom, such as thematic presentations, group discussions, and individual summaries. For instance, for students majoring in Integrated circuit, relevant knowledge as "Semiconductor Memory" and "Programmable Logic Devices" in DCLD were integrated into topics of group presentation, creating an atmosphere of flipped classrooms and fostering students' independent learning abilities.

4.3 Exercise Assignments after Class:

After class, teachers assigned targeted exercises on the network platform based on key points of each chapter, meanwhile they provided timely grading, explanations, or systematic summaries subsequently. Additionally, practical solutions to engineering examples, and supplementary knowledge beyond the classroom were uploaded to the online teaching platform's resource library for engineering students.

4.4 Three Stages of Experimental Sessions:

Experiments of the DCLD course typically consists of three stages: pre-lab preparation, in-lab experimentation, and post-lab reporting. Initially, online videos or pre-lab guidance on the teaching platform are to engage students with preliminary understanding of the experimental tasks, guiding and inspiring students' autonomous practice. During each experiment, teachers firstly introduced theoretical knowledge using case-based teaching methods and then encouraged students to complete each experimental task independently. Real-time guidance and interaction were provided during students' experimental operations. Noteworthily, in the nine progressive experimental projects of the DCLD course, confirmatory experiments, designed experiments, and comprehensive experiments are arranged from the easy to the difficult ones progressively, aiming to gradually enhance students' abilities of using circuit tools and programming practices, as shown in Figure 3 below.

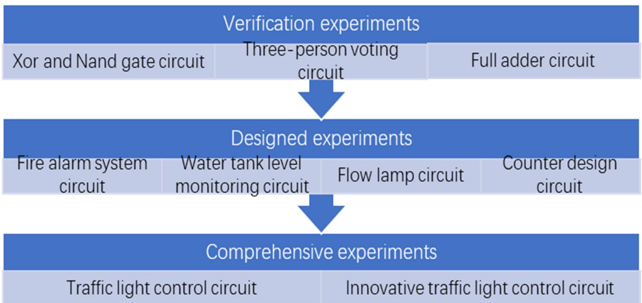

Figure 3: Design of the experimental project

In the reflection phase, students submitted their e-reports through the platform following the experiment session. Then teachers tracked their learning outcomes stage-by-stage based on the report results. In the final evaluation phase, students' comprehensive practical abilities to solve complex problems were assessed through randomized experimental exams without guidance of teacher.

Therefore, through scientifically-designed experimental projects, more communication and interactions between teachers and students are promoted, thus more students' learning enthusiasm are aroused. A deep integration of information means with subject knowledge could allow teachers to periodically guide and assess the practical programming, design, simulation, and innovative abilities of entire class or major during the experimental process.

5. Data Analysis and Continuous Improvement on Reforms

In addition to assess the achievement of course objectives in the seminar of 2023-2024 (1), we also conducted a satisfaction survey about the DCLD course through the social media attributes of the Rain Classroom teaching platform. Students provided 385 valid questionnaire responses at the end of the semester, covering majoring in Communication engineering, Computer science, Microelectronics, and Artificial intelligence, as in figure 4. These students will learn different subsequent professional courses respectively, who can also be counted as one similar category related to information engineering during learning DCLD course.

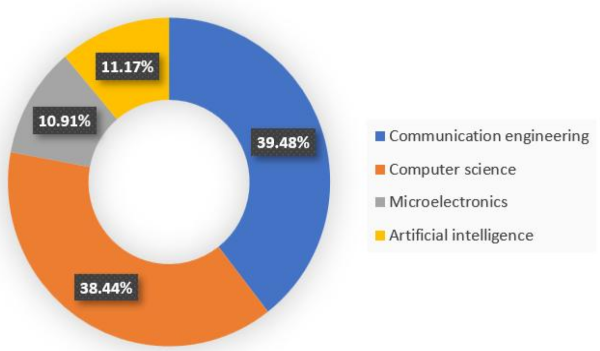

Figure 4: Participants of various majors

Through quantitative data analysis of questionnaire, SPSS was used to find the important influencing factor of satisfaction and to optimize the courses reform [9][10]. The statistical analysis found that, as shown in Figure 5, the highest influential factor was students' satisfaction with the teacher's guidance (20.99%), followed by benefiting the self-learning ability of students through nine experimental projects in DCLD course (18.52%). Thirdly, the influencing factor was developing students' ability of using FPGA technique tools through FPGA projects' procedure (16.05%). Therefore, based on the feedback from questionnaire, our ongoing efforts to improve the satisfaction to DCLD course should focus on the following aspects:

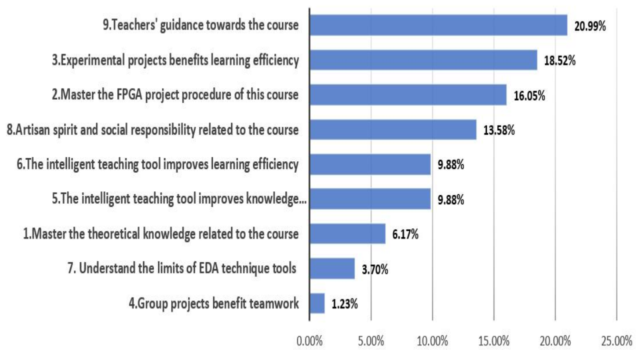

Figure 5: Analysis of student questionnaires

5.1 Cultivate the Strength of Young Teachers

As the guide and assistant of students in the learning process, teachers play a crucial role and can tailor their teaching methods according to the diverse majors and learning situations by combining online and offline methods [4]. Only when teachers continuously adjust their teaching methods and improve their strategies of blended teaching, can they stimulate students' autonomy, good interactions, innovative consciousness, and achieve satisfactory outcomes in the classroom [6]. Particularly, the teams of teachers of DCLD course, "Analog Circuits", and "Microcontrollers" respectively will assist teaching staffs from different majors through establishing discussion groups, forming a mechanism of mutual assistance, and enabling more communication, regarding the same course. Especially for newly recruited young teachers, for example, diverse training programs, sharing and discussion with outstanding scholars and experts in the same field, are necessary for them to participate in. Not only their subject knowledge and professional technical skills, but also their skills of blended teaching and the updated educational concepts, such as the TPACK teaching level model [2], the BOPPPS teaching model, and motivational theory [7] should be strengthened. Additionally, the university needs to assign young teachers to participate in more activities of various enterprises, industries, and associations, thereby teachers' practical abilities and engineering experience can be enhanced.

5.2 Adhere to Student-centered Teaching

No matter using online teaching platforms like Rain Classroom, or social media teaching tools such as MOOCs, micro-courses, and QQ online forums, teachers must ensure the student-centered design and adopt heuristic, inquiry-based teaching methods. The most crucial role of teachers is to guide students' deep thinking, inspire students to seek answers actively, thereby achieving the internalization of knowledge from low to high levels [6]. The learning process truly reflects the philosophy of CDIO-OBE. Meanwhile, data analysis from students' satisfaction surveys have shown that the dissatisfaction rate about teachers is only 6.5%, as in figure 6 bellow. Thus, the result showed that students majoring in engineering at our university felt satisfied with most DCLD teachers.

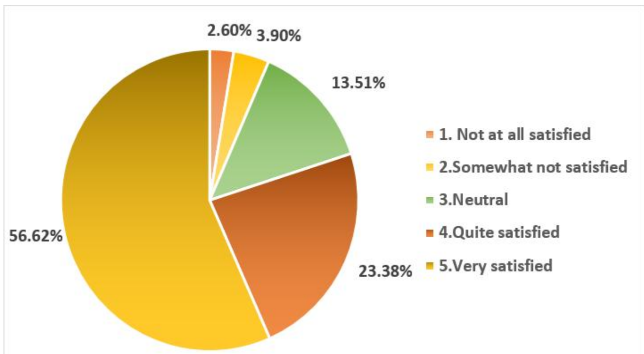

Figure 6: Students' satisfaction with teachers

In the questionnaire, 69.5% of students who spent more than 20 minutes on online teaching platform and mobile app for studying every day, said that they could actively participate in online learning because of the convenience of blended learning at anytime, anywhere. Moreover, 67% of students believed that blended learning has improved the efficiency of self-learning and knowledge understanding in the classroom.

5.3 Highlight the Importance of Experimental Projects

Experimental projects are the concrete embodiment of the

CDIO concept and an important part of the overall reform of DCLD course; the blended teaching process strengthens the close combination of three stages of experiments including pre-lab, in-lab, and post-lab with the information supervision of whole process [7]. Additionally, the evaluation of the entire DCLD course includes pre-lab preparation online, progressive training through nine experimental projects, reflection on experimental reports, and a final comprehensive experimental examination. Therefore, the feedback from questionnaire also confirmed that 70.4% of engineering students believe that experiments of DCLD course have extended knowledge and practical application [7]. And 69% of students have developed craftsmanship, patriotism, and social responsibility through the learning, while 61.3% of students are aware of the limitations of tools and technologies. Moreover, from the self-reported data of the survey, it revealed that the completion time for pre-lab preparation and experimental reports should be controlled within 0.5-1 hour, that has the greatest impact on students' self-consciousness and initiative. However, spending more than one hour might have a negative impact on students' sense of autonomy.

Additionally, the proportion of grades for the experimental part accounts for up to 25% of grades in the overall evaluation of DCLD course, including both formative and process assessments. Similarly, the overall evaluation of the DCLD course has also changed from a single evaluation mode into six parts' grades. From cultivating four course objective abilities for students, to addressing students' capability to solve complex practical problems during the experimental process, that fully reflects the student-centered teaching reform.

6. Inclusion

In order to promote the curriculum reform in our higher education, firstly it is essential to understand the reasons and objectives of reform before considering how to improve it. Therefore, we should start by addressing questions such as what talents we are cultivating, for what objectives we are teaching, and how we improve the integrated reform of the curriculum group [4], especially based on different students' majors. Thus, by meeting the needs of student development, the demands of contemporary digital industry, and the goal of building a digitalized higher education, we should integrate the CDIO-OBE concept into the entire talent training system covering knowledge and abilities, and then carry out a blended teaching reform from top to bottom [5].

This article takes the optimized DCLD course for students majoring in electronic information as an example, from the talent training plan to the course outline, to construction of distinctive graduation requirement, ability cultivation objectives of this major by the CDIO concept. Moreover, it presented different professional teaching teams, and explored ideological and flipped classroom mode, and amended different course objectives with major characteristics of electronic information. Finally, through end-of-term student satisfaction survey and course objective achievement reports, we obtain feedback for continuous improvement on teaching reform, which should include, but not be limited to, the following important aspects.

From the perspective of teaching team reform, teachers from various schools and majors have been included in our university's DCLD course teaching team since the first semester of 2023-2024. Especially for many newly recruited young teachers, they are encouraged to optimize teaching content design according to the new training plans and outlines of various majors, focusing more on inspiring students' high-level thinking and comprehensive abilities to solve complex engineering problems. In the implementation of blended teaching, both the efficient use of online teaching platforms conveniently and the maximum utilization of face-to-face communication, personalized guidance for students in classroom are emphasized. This ensures the effective connection of online and offline teaching content, thus maximizing the significance of blended learning reform [7]. Additionally, from 385 valid feedbacks of students' survey, training for professional knowledge, unified educational philosophy, and new teaching strategies for teachers is also crucial. It is expected to establish corresponding systems to enhance teachers' teaching skills such as the TPACK teaching strategy, and their commitment to efficiency and satisfactory of classroom.

Lastly, the survey feedback found that in this teaching practice of DCLD course, experimental teaching is of paramount importance in the reform process. Through the scientific design of experimental projects and the rational utilization of online teaching resources platforms, the new "norm" of blended teaching supports students being active explorer of self-learning and life-long learning, thus achieving various graduation objective or abilities as well. However, university should provide great support for information technology and high-level blended learning in the school, construct better facilities for majors, such as relevant experimental equipment, and the professional teaching mechanism for all staff to collaboration [11]. This is a complex and long-term project that requires continuous efforts.

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