

Teaching Reform of the "Principles and Technologies of IoT Control" Course Based on OBE-CDIO: Research on Concept-Project-Driven Teaching

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Abstract: In view of the problems existing in the traditional "Internet of Things Control Principles and Technology" course, such as the disconnect between theoretical teaching and engineering practice, insufficient training of students' engineering abilities, and low classroom participation, this article builds a "concept-project-driven" course teaching model based on the OBE and CDIO engineering education concepts. The course takes real engineering projects such as "Regional Traffic Collaborative Control System" as the main line, carries out systematic reforms around teaching philosophy, teaching model, teaching activities, teaching evaluation and other aspects, and integrates the Simulink virtual simulation platform and the intelligent transportation sand table experiment platform to form a teaching system of "combination of virtual and real, project penetration, and continuous feedback". Taking students majoring in Internet of Things engineering as the research object, the effect of the curriculum reform was analyzed through controlled experiments. The results show that after adopting the OBE-CDIO project-driven teaching model, students' average course grades, excellence rate and engineering practice ability have been significantly improved, and students' learning interest, independent learning ability and teamwork ability have been significantly enhanced.

Keywords: OBE; CDIO; Project-driven; IoT Control; Teaching Reform; Engineering Practice.

1. Introduction

With the rapid development of next-generation information technologies, such as artificial intelligence, the Internet of Things (IoT), and big data, traditional engineering education models struggle to meet the demand for cultivating application-oriented talent within the context of "New Engineering Education" [1]. For the IoT engineering major, "Principles and Technologies of IoT Control" is a core course that combines theory with practice. Students will need to master the theoretical contents of automatic control principle, system modeling, control algorithm, etc., and also have the ability to design and develop the Internet of Things system, that is, they must have practical skills. In the teaching of colleges and universities, the teaching theory often accounts for the majority, the knowledge points are still relatively fragmented, and there are not many hours left for practice. In this way, problems such as less practical links and weak engineering awareness of students will arise, and students will also reflect that it is difficult for them to apply the knowledge they have learned to real engineering scenarios [2,3].

OBE (Outcome-Based Education) is an educational concept that takes learning outcomes as a guide, and pays more attention to whether students final ability has been achieved [4]; the CDIO engineering education model puts the cultivation of the whole process of "conception-design-implementation-operation" of engineering projects in an important position [5]. In recent years, OBE and CDIO have gradually become the key theoretical basis for the construction of new engineering. However, looking at the existing research, the reform of many courses still stops at the level of "adding experiments" or "introducing projects", and lacks continuous and systematic engineering projects throughout [6,7]. The students still get a scattered understanding of the project, and do not really understand the

whole process of the development of the complete Internet of Things system.

Based on this, this paper will respond to the training needs of Internet of Things engineering professionals, and propose a "conceptual project-driven" teaching mode based on OBE-CDIO, and take "one person, one project, one lesson, one system" as the core concept, so that the course knowledge points can enter the whole process of continuous project development, so as to integrate knowledge learning and engineering practice more deeply. This study will also study and analyze the impact of this model on students engineering practice ability and learning effect through teaching experiments. It is expected to provide some references for the teaching reform of related courses of Internet of Things engineering in applied undergraduate colleges.

2. Analysis of Problems in Traditional Courses

2.1. Disconnect between Theoretical Teaching and Engineering Practice

The course "Principles and Technologies of IoT Control" has the characteristics of multidisciplinary intersection of automatic control theory, communication technology, embedded development and system integration, so the requirements for students' engineering practice ability will be relatively high. However, the traditional "Internet of Things Control Principle and Technology" course mainly adopts the mode of "theoretical teaching + confirmatory experiment"; in this model, although students can master the basic theories of PID control and system modeling, the complete project training is actually lacking. It is not easy to establish a systematic engineering thinking.

2.2. Severe Fragmentation of Knowledge Points

The content of this course will cover many knowledge modules such as automatic control principle, system modeling, sensor technology, data acquisition, communication protocol, control algorithm and execution device, and these knowledge modules actually have a strong correlation. However, in traditional teaching, the contents of each chapter are often independent of each other. Teachers will speak in the order of textbook chapters, and students will only passively receive the contents of independent chapters, in this way, it is not easy for students to understand the internal relations between the knowledge modules, and it is difficult to form a complete knowledge system.

2.3. Low Student Classroom Engagement

Most of the traditional classrooms are still mainly taught by teachers. Students are often in a passive learning position, and there are few opportunities to think independently and take the initiative to do engineering exploration. Their learning motivation is more from classroom exercises, homework and examination requirements, not from the interest in the project content itself. This is especially true for students in application-oriented undergraduate colleges. Once driven by the lack of real engineering scenarios and project tasks, it is not easy for students to establish professional identity and engineering awareness, and the learning effect of the course will be affected.

2.4. Insufficient Cultivation of Engineering Capabilities

Under the background of "New Engineering", the training of Internet of things engineering professionals will pay more attention to students' ability to solve complex engineering problems independently. However, the traditional course assessment method is mainly based on theoretical examination, and the evaluation of students' system design ability, engineering practice ability and innovation ability is not sufficient. The evaluation focuses on the result evaluation of test scores, rather than the process evaluation of students' practice, or the formative evaluation of the results.

In the traditional teaching mode, although students can complete a single experimental task, once it comes to system scheme design, hardware selection, communication protocol configuration, control algorithm optimization and system joint debugging, the ability is relatively weak, and they do not have the ability to complete a complete Internet of Things system. In the face of open engineering problems, students generally have the following situations:

First, the overall design ability of the Internet of things system is not enough;

Second, the innovation consciousness is weak, personalized solutions are not easy to put forward;

Third, the ability to analyze engineering problems is lacking;

Fourth, team cooperation ability and project management experience are relatively few.

Therefore, this study takes how to improve students' engineering practice ability and innovation ability through curriculum reform as an important reform direction based on the course of "Principles and Technologies of IoT Control".

3. Design of the OBE-CDIO Course Teaching System

3.1. Construction of the OBE-CDIO Teaching Philosophy

The OBE education concept will put "results-oriented" in an important position, and will also pay more attention to what knowledge, ability and quality goals students have after the end of the course. The CDIO engineering education model pays more attention to the cultivation of the whole life cycle of the project, and puts the students' practical ability training in the real engineering environment in a prominent position.

In this study, the OBE and CDIO concepts are deeply integrated, and the ability to independently complete the design and development of the Internet of things control system is determined as the core goal of the course "Principles and Technologies of IoT Control", so as to construct a three-dimensional collaborative training system of "knowledge-ability-quality". The course design process also needs to be reformed. Instead of simply emphasizing the teaching of knowledge points, the teaching content and teaching activities should be reversely designed around the achievement of students' final ability.

The whole teaching process of the course will be carried out according to the four stages of CDIO, which is divided into the following steps:

(1) Conceive: guide students to clearly conceive the specific needs of the IoT system and make a reasonable plan for the project;

(2) Design: organize students to complete the design of the overall architecture of the system, and at the same time design the core control scheme;

(3) Implement: with the help of prototype construction, coding implementation, experimental verification and other links, let students really do it, land the design, and deepen the understanding of the principle boundary conditions in debugging and trial and error;

(4) Operate: Perform system deployment and operation optimization, requiring students to backtrack design defects based on operating data, and then iterate and optimize, thereby forming a closed loop of 'practice-reflection-re-learning'.

After integrating the whole life cycle engineering process of CDIO into the whole process of teaching, students will take real engineering problems as the starting point, enter the project situation with the concepts, principles and methods learned in the class, and complete the call, inspection and reconstruction of knowledge in the complete process of demand analysis, scheme design, prototype implementation, system joint debugging and iterative optimization.

3.2. Design of the "Concept Project-Driven" Teaching Model

Unlike traditional courses that follow a sequential, chapter-by-chapter teaching approach, this course employs a project-driven model based on the concept of "one person, one project; one lesson, one system." At the beginning of the course, instructors use typical case studies—such as smart transportation, smart home systems, and smart agriculture—to guide students in selecting specific application scenarios based on their interests and developing their own conceptual projects.

For instance, in the "Regional Traffic Cooperative Control

System" project, students are required to complete the following tasks:

- (1) analysis of traffic flow demands;
- (2) design of the control system architecture;
- (3) deployment of sensors and edge nodes;
- (4) design of control algorithms;
- (5) system debugging and optimization.

The topics covered in each chapter revolve around these student projects. For example, when learning about PID control algorithms, students apply them to the dynamic control of traffic lights; when studying data acquisition and transmission, they perform real-time collection and uploading of traffic data.

Driven by continuous engineering projects, abstract theoretical knowledge can fall into specific engineering situations. Students will not only stop at the level of conceptual memory, but will gradually see the relationship between knowledge and gradually build a complete knowledge system in the process of design and implementation.

3.3. Implementation of the Full-Process CDIO Teaching Model

In the Conceive stage, students will first investigate the actual IoT application scenarios, and complete the demand analysis accordingly; after entering the Design stage, the system architecture design and hardware selection will be implemented; in the Implementation stage, the control algorithm development and system debugging will be carried out; then to the Operate stage, it is necessary to use the intelligent transportation sand table to carry out the system deployment and operation test. The four stages of CDIO will run through the whole process of curriculum teaching, and will also organically integrate curriculum knowledge points, teaching activities and ability training objectives, so as to embody the engineering education concept of "learning by doing and doing by learning". Figure 1 shows the implementation process of concept project driven teaching based on CDIO.

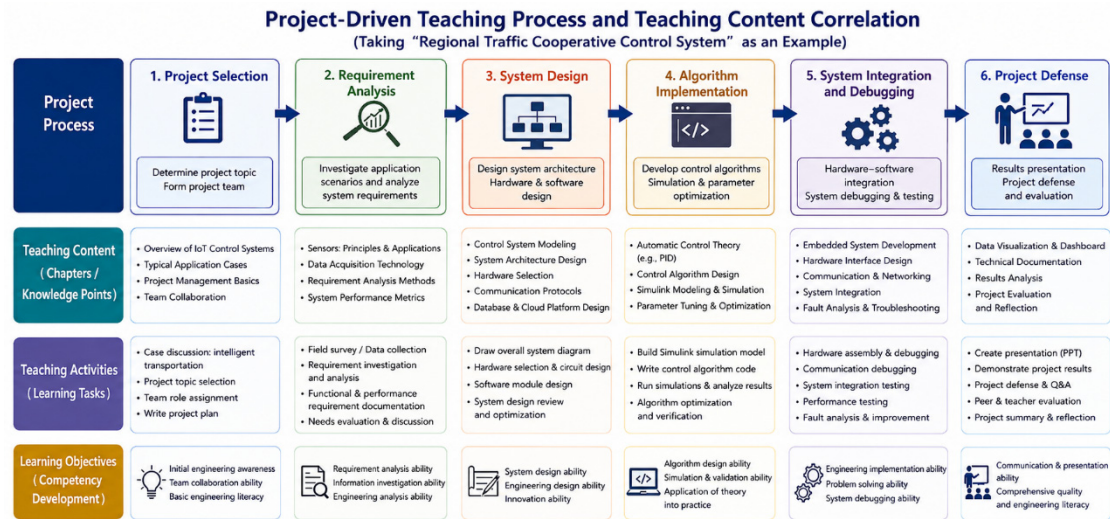


Fig 1. Process of concept-driven project teaching based on CDIO

It can be seen from Figure 1 that a clear mapping relationship has been established between the project implementation process and the curriculum knowledge system. With the continuous advancement of project development, students will complete knowledge learning, ability training and engineering practice step by step. Therefore, the course teaching will no longer stop at "knowledge imparting", but gradually turn to "ability training".

3.4. Design of the Teaching Evaluation Mechanism

On the basis of OBE results-oriented concept and CDIO

engineering education idea, the course builds an evaluation system that combines "process evaluation + final evaluation". Compared with the traditional evaluation system, the reformed evaluation will put students' performance in the learning process more important, so the process evaluation accounts for 60%, and the final evaluation accounts for 40%. The process evaluation will be designed according to the four stages of CDIO. As shown in Table 1, it corresponds to the four stages of project conception, overall design of the system, specific implementation of the project and smooth operation of the system. The focus of the investigation will be on students' needs analysis ability, system design ability, engineering practice ability and comprehensive application ability.

Table 1. Teaching evaluation mechanism

Key Indicator	Secondary Indicator	Corresponding CDIO Stage	Weight
Project Conception	Requirement analysis, investigation	Conceive	10%
System Design	Solution design, architecture design	Design	15%
Project Implementation	Algorithm development, system integration	Implement	20%
Project Operation	Testing, optimization, defense (presentation)	Operate	15%
Theoretical Examination	Comprehensive assessment	—	40%

The final examination adopts the combination of theoretical knowledge and comprehensive design. On the one

hand, it looks at the students' mastery of basic theoretical knowledge, on the other hand, it also pays attention to the students' ability to solve complex engineering problems.

It can be seen from Table 1 that this evaluation system puts the collaborative evaluation of knowledge goal, ability goal and quality goal into practice, and can also better reflect the whole process of students' learning.

4. Analysis of Teaching Effectiveness

4.1. Design of the Teaching Experiment

In this study, two different batches of students studying this course in the Internet of Things engineering major were selected as the research objects. Among them, the first batch followed the traditional teaching mode ; the second batch adopts the concept project-driven teaching mode based on OBE-CDIO. After that, the research will combine the course performance, engineering ability evaluation and student questionnaire to analyze the effect of teaching reform.

4.2. Comparative Analysis of Student Grades

From the comparison results of Figure 2, it can be seen that the average score of the experimental teaching group reached 83.6 points, while that of the traditional teaching group was 72.8 points ; in terms of the excellent rate, the experimental teaching group is also 23.3 percentage points higher than the traditional teaching group. These two indicators are sufficient to show that the project-driven model can indeed effectively enhance students' ability to understand and apply curriculum knowledge, and the overall performance of students in the experimental group will be significantly better than that of the traditional teaching group.

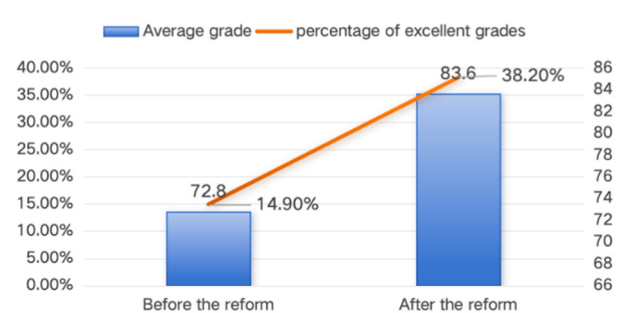


Fig 2. Average grade and rates of excellence before and after the reform

At the same time, the improvement of students' scores on comprehensive design questions and practical questions will be more obvious, which also shows that the curriculum reform not only raises the level of theoretical mastery, but also promotes the improvement of engineering practice ability.

4.3. Analysis of Engineering Practical Skills

In order to further verify the effect of teaching reform and to evaluate students' performance in the learning process more clearly, this study evaluates students from the aspects of system design ability, hardware debugging ability, control algorithm application ability and team cooperation ability.

As shown in Figure 3, the students in the experimental group are significantly better than the traditional teaching group in all ability indicators ; among them, the system design ability, hardware debugging ability and control algorithm application ability are 1.4 higher than the traditional teaching group.

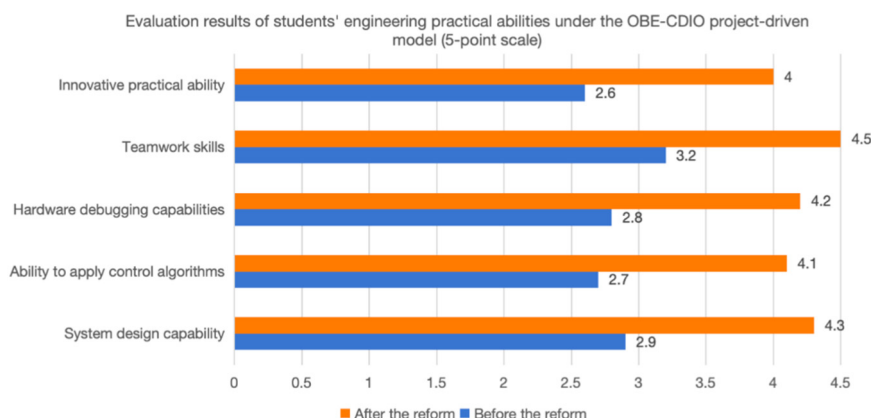


Fig 3. Comparison of engineering practical capabilities

After the analysis of the researchers, it is believed that the continuous concept project can help students to establish a complete engineering thinking, and also improve the ability of knowledge transfer and comprehensive application.

4.4. Analysis of Student Satisfaction

The researchers distributed questionnaires to students, and the results of the questionnaire will show that most students have a positive attitude towards the project-driven teaching model. As shown in Figure 4, 92.10% of the students think that project-driven teaching can raise their interest in learning; 88.70% of the students think that the CDIO model has enhanced the engineering consciousness; 93.20% of the students think that Simulink simulation can help improve their understanding ability; 90.10% of the students think that

group collaboration is helpful to improve their practical ability; 86.50% of the students are more willing to take the initiative to learn. It can be seen that this model can effectively stimulate students' learning enthusiasm and improve classroom participation.

5. Summary

Based on the OBE-CDIO concept, this study constructs the concept project-driven teaching mode of the "Principles and Technologies of IoT Control" course, and verifies the effectiveness of this mode with the help of real teaching practice. From the verification results, in this mode, teaching can effectively improve students' engineering practice ability, autonomous learning ability and innovation consciousness, and the teaching quality will also be improved. Students can

better realize "learning by doing and doing by learning", and they will be more interested in teaching content. Next, the construction of curriculum resources will continue to improve, and the multiple teaching evaluation methods will be further explored, so as to provide more reference for the teaching reform of engineering courses under the background of new engineering.

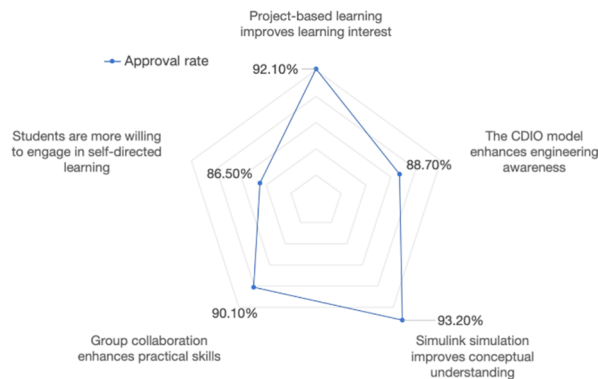


Fig 4. Student satisfaction

Acknowledgments

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References

- [1] Ramirez-Mendoza, R. A., Morales-Menendez, R., Iqbal, H., & Parra-Saldivar, R. (2018). Engineering Education 4.0: proposal for a new curricula. In 2018 IEEE Global Engineering Education Conference (EDUCON) (pp. 1273–1282). IEEE. <https://doi.org/10.1109/EDUCON.2018.8363376>.
- [2] Huang, D. H. (2025). Innovative interactive instruction to enhance learning behaviors. *Journal of Innovation & Knowledge*, 10(1), 100641. <https://doi.org/10.1016/j.jik.2024.100641>.
- [3] Abuhassna, H., & Alnawajha, S. (2023). Instructional design made easy! Instructional design models, categories, frameworks, educational context, and recommendations for future work. *European Journal of Investigation in Health, Psychology and Education*, 13(4), 715–735. <https://doi.org/10.3390/ejihpe13040054>.
- [4] Syeed, M. M. M., Shihavuddin, A. S. M., Uddin, M. F., Hasan, M., & Khan, R. H. (2022). Outcome based education (OBE): Defining the process and practice for engineering education. *IEEE Access*, 10, 119170–119192. <https://doi.org/10.1109/ACCESS.2022.3219477>.
- [5] Yuan, X., Wan, J., An, D., Lu, J., & Yuan, P. (2024). Multi-method integrated experimental teaching reform of a programming course based on the OBE-CDIO model under the background of engineering education. *Scientific Reports*, 14(1), 16623. <https://doi.org/10.1038/s41598-024-67667-6>.
- [6] Law, M. Y. (2022). A review of curriculum change and innovation for higher education. *Journal of Education and Training Studies*, 10(2), 16. <https://doi.org/10.11114/jets.V10i2.5448>.
- [7] Li, X. (2023). Reform of higher education curriculum in the new era. *The Educational Review, USA*, 7(7), 943–947. <https://doi.org/10.26855/er.2023.07.017>.