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Development of Teaching Platform for Electrical Control and PLC Training Courses

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Abstract

With the advancement of Industry 4.0, the training courses of electrical control and PLC are facing the need for teaching reform in keeping pace with the development of the times. Guided by the CDIO model, this paper analyzes the problems of the existing PLC course teaching and proposes reform strategies. Through the teaching platform composed of laboratory manuals and developed teaching equipment, students' practical application ability and teamwork ability are improved. Taking the position control project of PLC screw slide table as an example, the project-based teaching of four stages of conception, design, implementation and operation is implemented, and the teaching equipment is developed modularly, so that it has many advantages and meets the current needs. The practical results show that the reform significantly improves students' practical skills and teamwork ability, provides a useful reference for teachers to carry out reform teaching, and helps to cultivate technical talents who meet the needs of modern engineering.

Keywords

Teaching Equipment; PLC Training Courses; CDIO; Practical Application Ability; Teamwork.

1. Introduction

With the arrival of the fourth industrial revolution and the rapid development of the knowledge economy and the pace of technological innovation, to cope with the global new round of industrial transformation and achieve the goal of a manufacturing powerhouse, "Made in China 2025" clearly states the need to achieve high-end and intelligent development of the manufacturing industry through technological innovation and industrial upgrading[1]. it also points out the need to deepen the reform of the education system and explore education models and mechanisms that adapt to the development needs of the new era manufacturing industry.

Since 2017, the Ministry of Education has carried out a major reform and innovation in traditional engineering higher education to continuously promote the construction of new engineering disciplines. The "Fudan Consensus" emphasized the importance of the construction of new engineering disciplines and proposed the direction of engineering education reform for the future. The "Tianjin Action" actively carried out curriculum system reform and strengthened practical teaching. The "Beijing Guidelines" provided specific guidance and reference for colleges and universities [2]. In order to adapt more quickly to the needs of national development, engineering education must undergo strong reform and innovation to cultivate a variety of innovative engineering technical talents. The reform of related engineering practice course teaching is also urgent. PLC (Programmable Logic Controller), also known as the programmable logic controller, is a core component of industrial automation and intelligent manufacturing, occupying an important position in the field of engineering, and is also an important part of the automation engineering practice course. The quality of electrical control and PLC practice courses is related to the cultivation of students'

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comprehensive skills and thinking abilities. However, there are currently problems such as the experimental content of electrical control and PLC practice courses not meeting the needs of enterprise development and the teaching platform being outdated. This paper will mainly discuss the problems faced by electrical control and PLC training courses in the context of engineering education reform, and develop a supporting teaching platform based on the CDIO model to create teaching equipment that meets the requirements to meet the needs of professional and skilled talents in today's society.

2. Analysis of the Current Situation of the Curriculum

The Electrical Control and PLC training course is an important part of training students to solve practical problems and improve their skills in various aspects through the knowledge they have learned. However, the current curriculum teaching is still teacher-centered, theoretical teaching is the mainstay, with empirical teaching, and is carried out through face-to-face classroom teaching, and there are mainly the following problems.

2.1 The Content of the Teaching Experiment is Contrary to the Market Demand

The experiment manual is an important basis for students and teachers to carry out experiments, but there is a deviation between the experimental content and the actual needs of enterprises, and there will be the following problems:

1)The content learned in the experiment is not closely related to the enterprise, the actual content is separated from the needs of the enterprise, and the experimental content is updated and iterated slowly.

2) The experimental instruction is written in too much detail, which restricts the space for students' independent exploration and innovation, and is not conducive to cultivating students' innovative thinking and problem-solving ability to separate the actual content from the needs of enterprises.

3) The lack of project-based teaching content references makes it difficult for students to fully understand the complete process of a project from initiation to completion.

2.2 The Teaching Experiment Equipment is Old

As a carrier for students to carry out experiments, the teaching experiment platform is a very important part of the curriculum, and many domestic universities are obtained through imports, and they are relatively old, and their main problems are:

1) the price is expensive, the replacement is slow, the cost of trial and error of students is high, once the equipment is damaged, it will cause greater economic loss and is difficult to repair, the cycle of equipment upgrading is longer, and it is difficult to keep up with the pace of technological development.

2) The integrated design cannot be iterative, and the experiments that can be carried out are relatively simple, which is not conducive to cultivating students to carry out innovative development, and it is difficult to meet the needs of engineering education reform.

3) It is difficult to get started, and the learning cost of students is high, which leads to confusion and frustration when students face complex PLC programming and debugging tasks.

2.3 The Evaluation and Assessment Mechanism is Single

Assessment of electrical control and PLC training courses is mainly based on written examinations, which to a certain extent reflect students' mastery of knowledge points, and the evaluation and assessment mechanism based on written examinations has the following problems:

1) The evaluation method is too simple, the lack of comprehensive evaluation, only based on the written test results can not intuitively reflect the student's mastery of the relevant content, can not support the student to solve practical problems in a complex environment.

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2) The evaluation content is single, lacks process assessment, and the evaluation content only focuses on attendance and experimental data, ignoring the evaluation of cooperation, innovation and problem-solving ability, which is not conducive to the comprehensive quality development of students.

3) The content of the assessment focuses on the memory and understanding of theoretical knowledge, but is not enough to evaluate students' hands-on skills and engineering application ability.

3. Basic Theories and Reform Ideas of Electrical Control and PLC Training Courses

3.1 Basic Theories

The CDIO (Conceive-Design-Implement-Operate) education model was proposed by the United States Massachusetts Institute of Technology (MIT)[3], which is composed of four parts: Conceive, Design, Implement, and Operate, and is guided by project-based teaching. The CDIO education model is an advanced education model in the field of engineering, which occupies an important position in the reform of engineering education, and is an internationally recognized education model, which aims to narrow the gap between engineering education and industry by cultivating students' comprehensive ability and practical ability, and provide engineering science and technology talents for enterprises.

At the heart of the CDIO model lies in its integrated approach to education, which emphasizes the combination of practical and theoretical knowledge of engineering, as well as students' active learning and experience accumulation in real-world engineering projects. This model encourages students to develop their technical knowledge, individual skills, teamwork and communication skills by participating in real-world engineering projects.

The introduction of the CDIO engineering education model into the electrical control and PLC training course can well solve the shortcomings of traditional experimental teaching[4-6], and the CDIO can be used as the theoretical basis of the curriculum to carry out the teaching reform, which meets the requirements of the engineering curriculum reform in the context of engineering education reform, and uses it as the theoretical basis to build teaching equipment so that students can complete more meaningful experiments, and the course teaching can pay more attention to the cultivation of students' comprehensive practice, innovative thinking and problem-solving ability. In addition, this model focuses on the combination of practice and theory and the improvement of engineering practice ability, which can bring a series of positive effects to the electrical control and PLC training courses, and help to cultivate high-quality technical talents who are more in line with the needs of modern engineering.

3.2 Reform Ideas

As an important basis for carrying out experiments, the teaching experiment manual should first reflect the educational advancement of the CDIO model, and the experimental content should be guided by the project system, and integrate the four stages of the CDIO model, namely conception, design, implementation and operation, into the experimental teaching, so as to improve students' engineering practice ability and build innovative thinking. Secondly, the content and methods of evaluation should also be diversified, including not only students' theoretical knowledge, but also project participation, teamwork ability, problem-solving ability and innovation ability. Process evaluation should be an important part of the evaluation system, focusing on students' performance and progress in the process of practical training, not just the final result.

Second, the teaching platform needs to be scalable and modular, and the equipment should allow teachers to add or upgrade components according to the needs of the curriculum and the level of competence of students. It should be easy to iterate on so that it can be updated and maintained in a timely manner, ensuring that students are exposed to the latest technologies and applications. Ensuring the cost-effectiveness and safety of the equipment is a key factor in its widespread adoption and adaptation to the budgetary constraints of educational institutions, Students will make mistakes

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in the process of experiments, so the teaching equipment should have a certain error tolerance and finally its ability to be integrated and integrated to support interdisciplinary and blended learning models[7].

4. The Specific Content of the Reform of the Electrical Control and PLC Training Course

4.1 Optimize the Lab Manual

The experiment manual is project-oriented, presenting students with a complete project requirements specification, understanding the project to achieve the goal, and building a learning framework based on the CDIO education model in order to complete the goal, as shown in Table1.

Table 1. Three Scheme comparing

Steps	Content
Conceive	**Goal setting:** Design a PLC linear screw position controller that can be controlled by the touch screen Requirement **Analysis:** determine the performance indicators that the system needs to achieve, with forward and backward, front and rear limit functions, relative positioning functions and absolute positioning functions
Design	**Schematic design:** Determine the required equipment and understand how to use it, and draw experimental schematics, including the connection of PLC, stepper motor, driver, limiter and encoder **Programming:** Write PLC and touch screen programs to achieve precise control of the linear screw slide
Implement	**Hardware construction:** complete the wiring and assembly of hardware according to the schematic diagram **Software programming:** clarify the requirements, write and debug the PLC program, realize the control logic, and ensure that the program meets the project requirements **Test and verification:** system testing to verify the control accuracy and stability
Operate	**System commissioning:** Debugging the system to ensure that it can operate stably under various working conditions **Performance evaluation:** record experimental data to evaluate whether the system performance meets the design requirements

By enumerating the four stages of conception, design, implementation and operation, students are provided with a structured learning path.The experimental content covers the whole process from theoretical learning to practical operation, and realizes the goal of combining theory with practice.

The experiment focuses on cultivating students' teamwork problem-solving ability, providing specific tasks and responsibilities for team members, and students can be responsible for different tasks through their own characteristics, and can also make corresponding adjustments on this basis to ensure efficient cooperation in the project, as shown in Table2.

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Table 2. Student's division of labor

Office	Job description
Student A: Project Manager and Hardware Engineer	**Project management:** responsible for the overall project planning, timeline formulation and resource coordination, and complete the writing of the project requirements specification **Hardware design:** determine the hardware selection, complete the schematic design and wiring **Hardware construction:** complete the wiring and assembly of the hardware according to the design schematic **Team Coordination:** Ensure smooth communication between the team and solve problems within the team
Student B: Software Engineer	**Software design:** responsible for the design of PLC programs and touch screen programs **Programming implementation:** write and debug PLC programs to implement control logic **Software testing:** Collaborate with C to ensure that software functions meet the design requirements
Student C: Test Engineer and Documentation Writer	**System Testing:** Responsible for system testing to verify control accuracy and stability **Performance evaluation:** Record experimental data to evaluate whether the system performance meets the design requirements **Document writing:** Write experimental reports,including analysis and experience of experimental results **Team Communication:** Assist A with internal team communication and external reporting

In the process of writing the experiment manual, students need to record the corresponding experimental data and troubleshooting content, including recording fault phenomena, analyzing the causes and finding fault points, on the one hand, improving students' problem-solving skills. On the other hand, it serves as the basis for teachers to carry out process evaluation.

In terms of evaluation, the experiment manual pays attention to the diversification of evaluation content and evaluation methods, in order to promote the comprehensive quality and personalized development of students, and the evaluation diversification can better evaluate students' abilities and support different learning styles. The results of the practical training course are shown in Table3.

Table 3. Evaluation and Assessment Criteria

Evaluation indicators	Weighted percentage
Pre-experiment Knowledge Check Status	10%
Class Attendance	10%
Experiment Achievement Degree	30%
Report Completeness	20%
Experimental Problem-Solving Ability	10%
Innovativeness of Experimental Methods	10%
Teamwork Ability and Division of Labor	10%

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4.2 Development of Teaching Equipment

There are two main reasons for the development of the teaching platform [8], the first is to make it a carrier of the experimental manual, which is highly compatible with the experimental manual. The second is to apply the theory of CDIO education model to the teaching platform. In order to better reflect the advantages of modular design, the teaching platform consists of two parts: the hardware components on the control side and the load side.

The first part is the control end, the control end is used to control the load side, and the hardware part of the control end comprises: The control end is used to control the load side Three-phase power line, 2p air switch, power main switch, AC contactor 220V/380V, 24V DC power supply (2 units), binding post, frequency converter, stepper motor driver, PLC, STC51 MCU, STM32 MCU, DC motor governor, touch screen (2), servo motor driver and several wiring harnesses(Figure1).

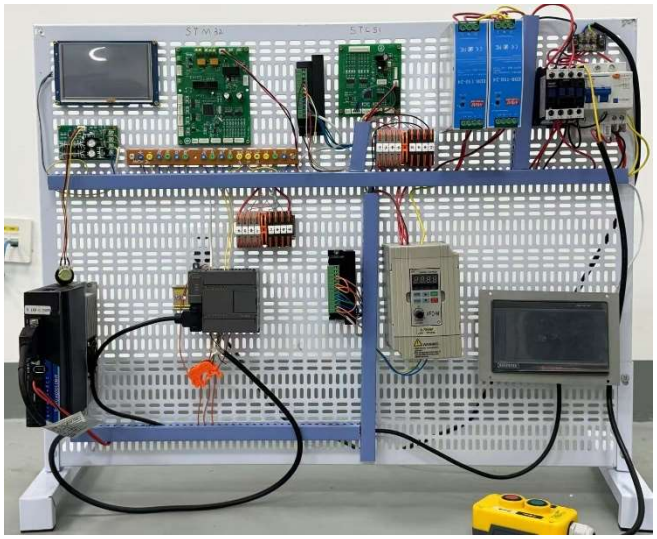

Figure 1. Control-side hardware components

The second part is the load side, the load side is responsible for executing the instructions issued by the control end, completing the specific work task, the hardware part includes: stepper motor, servo motor, DC motor, AC motor, permanent magnet synchronous motor, encoder, stepper motor linear screw slide, pressure sensor, solar panel and temperature sensor(Figure2).

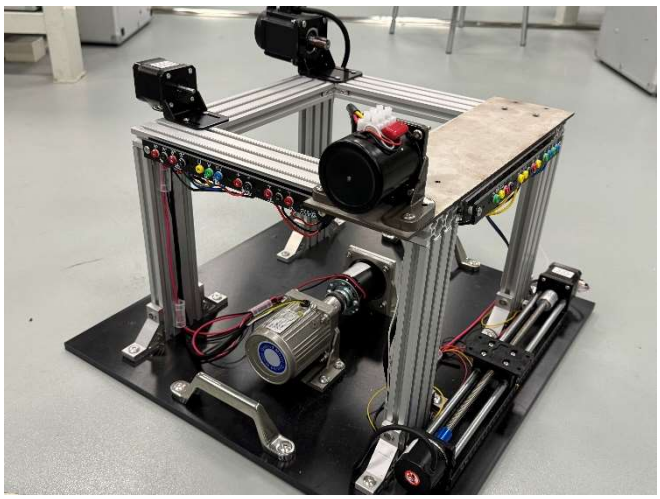

Figure 2. Load-side hardware components

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In order to reduce students' learning costs and stimulate students' interest in learning, the platform has made a series of adjustments. Wiring is an important part of the experiment, has a pivotal role, but its boring and cumbersome nature on the one hand for the improvement of students' ability is very small, on the other hand, increase the cost of student learning, so the platform innovatively changes the wiring mode from "screw mode" to "plugging mode", all motor input interfaces and control terminal output ports at the load end are changed to the way of terminal post sockets, and mark the interface name, students look for the interface of the load end and the control end that need to be connected in the process of use, and Plug it in with the wiring harness that comes with the platform. In addition, the platform provides multiple DC power interfaces, and provides a debugged downloader, plug and play. As shown in Figure3 to 4.

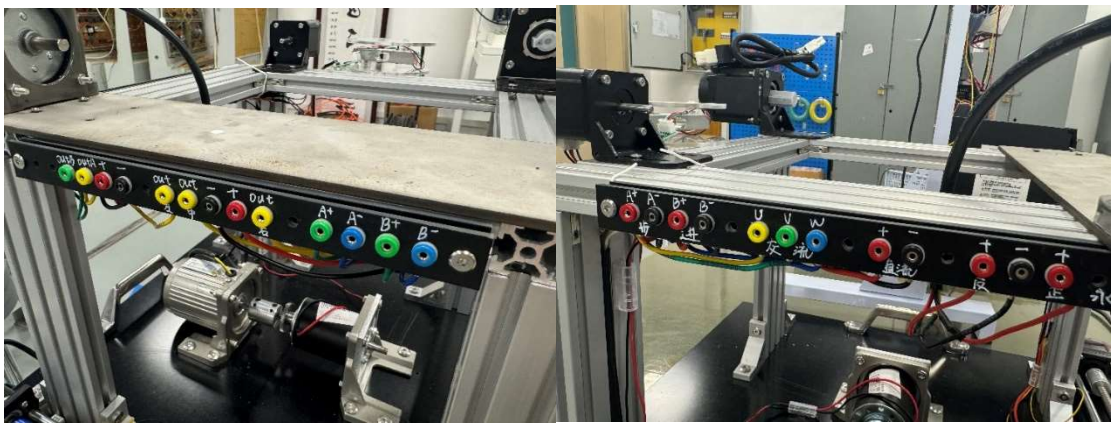

Figure 3. Load-side interface(right)

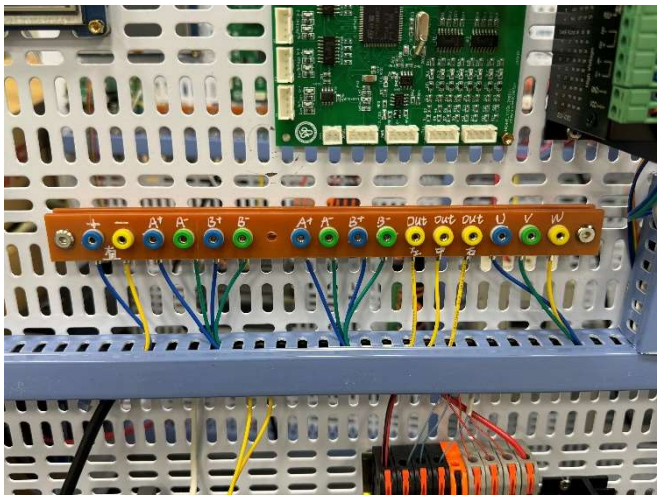

Figure 4. The control-side interface

4.3 Completion of Project Development

This paper takes the PLC screw slide table position control project as an example, and completely explains the specific development process of the project guided by CDIO:

1)Project objectives

The linear screw slide table is controlled by PLC [9], and the heavy object is transported from position 5 to position 15 by means of relative positioning and absolute positioning, the speed is maintained at 5mm/s, the position range is limited to 2-28, the speed adjustment range is 0-15mm/s, the speed and positioning are displayed in real time, and the use of EPLAN, GX Works and YKBuilder software is mastered.

2)Implementation of project tasks

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Including schematic design, PLC programming, touch screen programming, and hardware wiring and debugging. As shown in Figure5 to 8.

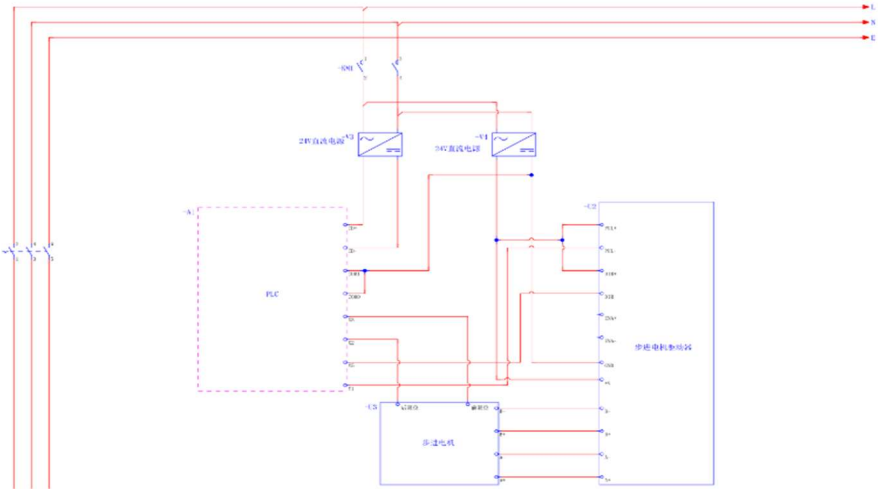

Figure 5. Schematic

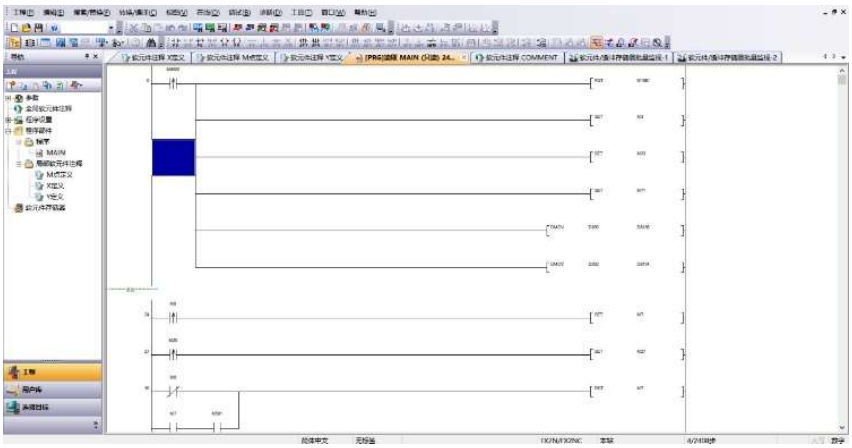

Figure 6. PLC program

Figure 7. The Touchscreen Program

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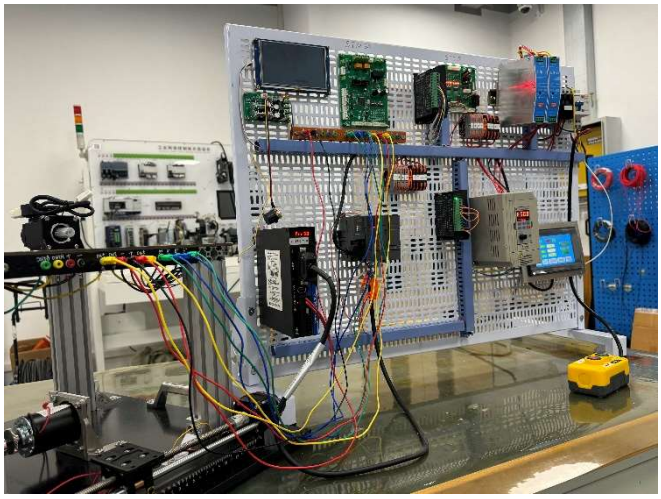

Figure 8. Hardware wiring

3) Evaluation and assessment

According to the evaluation and assessment criteria in Table 3, the teacher scores the students' achievements and provides guidance on the areas where the students' abilities are weak.

5. Effectiveness of Platform Reform

Ten sets of the teaching platform have been assembled, and the supporting experimental manuals have been applied to the training courses on the principle and application of PLC in universities, and the following results have been achieved so far.

5.1 Improve Students' Practical Application Ability

Practical training courses using the CDIO education model enhance students' practical application ability. Students transform theoretical knowledge into the ability to solve real-world engineering problems by participating in the entire process from ideation to implementation in a project-driven learning environment. In addition, through teamwork, students are able to develop soft skills such as communication, coordination, and project management. In this experiment, the same group of students re-opened the electrical control and PLC training course, and the second teaching test, and the results of the students' performance before and after the teaching reform are shown in Figure 9.

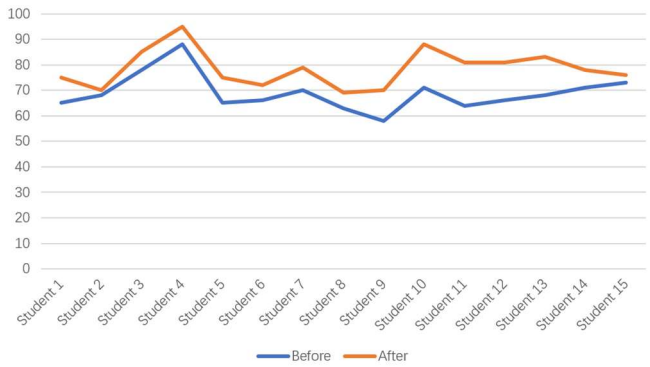

Figure 9. Student achievement results before and after the teaching reform

5.2 Develop Students' Teamwork Skills

In the CDIO model, students are assigned to teams with clear responsibilities for effective communication and collaboration. The interdisciplinary teamwork model exercises students' teamwork skills, leadership and sense of responsibility.

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5.3 Provides a Useful Reference for Teachers to Carry out Teaching Reform

The CDIO model provides teachers with an innovative pedagogical framework that closely aligns course content with the needs of industry. Teachers can use this model to design the curriculum, ensure that teaching activities are consistent with actual engineering practices, and design relevant experiments that meet the needs of the training based on the teaching equipment provided. At the same time, teachers are able to help students overcome learning barriers by observing their performance in the project and providing them with personalized guidance.

6. Conclusion

This paper discusses the current situation and reform strategies of electrical control and PLC training courses in the context of engineering education reform. Through the introduction of the CDIO education model, the creation of teaching equipment, the improvement of teaching effect and student experience, the goal is to improve students' comprehensive ability and teamwork ability, and cultivate professional and skilled talents who meet the requirements of enterprise employment.

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