

Research on PBL Blended Learning based on Interdisciplinary Subjects

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Abstract: To tackle the pedagogical challenges stemming from the disjointedness between the courses "Digital Logic Circuits" and "Computer Organization Principles", along with the gap between theoretical instruction and industry practices, this research has developed an PBL (Problem-Based Learning) hybrid teaching model based on interdisciplinary subjects. This model centers on the "Single-Bus CPU Design and PLC (Programmable Logic Controller) Industrial Integration" project to link cross-course knowledge points and builds a closed-loop teaching process of "before-class project preview, in-class project practice, and after-class industry scenario expansion" to map the intrinsic connection between these two courses from "fundamental logic to system architecture". The teaching framework incorporates a tiered task system and multidimensional evaluation mechanism which incorporates industrial elements such as domestic CPU development and industrial control. This approach not only can contribute to break down knowledge silos but also can achieve the tripartite goal of "knowledge transmission-capability cultivation-value guidance". Practical implementation demonstrates that this model effectively enhances students' interdisciplinary application skills and engineering practice literacy. It's can provide reproducible reference paradigms for the teaching reform of foundational courses in computer science.

Keywords: PBL Problem-based Learning; Interdisciplinary; Hybrid Teaching.

1. Introduction

With the deepening advancement of China's innovation-driven development strategy such as "Made in China 2025" and "AI+", the demand for computer science and technology professionals in the new economic landscape has shifted from "single knowledge holders" to "application-oriented, skilled and innovative engineering compound talents". However, there are some issues with the traditional talent cultivation model which includes fragmented theoretical curriculum systems, practical teaching that leans towards verification and disconnect with Industrial demands. In recent years, the educators have been exploring interdisciplinary, project-based, and blended teaching methods to address this challenge. Xu [1] presented the "Harbin Institute of Technology New Engineering "II Plan" and emphasized integrating theory with practice, combining classroom instruction with project-based learning, driving solutions through problem-solving, and balancing academic and practical training. Wang [2] promoted project-based teaching with "real-world projects" integrated throughout the curriculum in basic courses for computer and electronic information majors. Peng [3] explored the educational philosophy of this dual-driven integration which can promote educational development, drive technological innovation, and cultivate high-quality innovative talents who can satisfy the demands of modern computer industries. Wu [4] proposed the theoretical teaching contents for each course and the computer software required for solving various models according to the principles of course cluster construction, which can improve students' ability to systematically model and solve complex problems. Zhao [5] deeply explored the application of PBL teaching model in the practical teaching by actively conducting both in-class and out-of-class practical teaching. He broke traditional classroom constraints and guided students to engage in real-

world engineering practices. Hao [6] proposed an adaptive signal processing course reform method based on "PBL+ flipped classroom." Guided by practical engineering challenges in research projects and employing the flipped classroom methodology, this approach achieves organic integration of theoretical instruction with engineering practice. Bi [7] proposed a restructured EDA technology practice curriculum system based on "graph tree + PBL" which combines online self-directed learning with offline project implementation to drive students to apply acquired knowledge in solving real-world engineering problems effectively. Yin [8] developed a blended teaching model integrating OBE (Outcome-Based Education) and PBL to explore its application in AI education for undergraduate and graduate programs. Tian [9] reformed blended teaching models for core computer science courses and used digital education opportunities to explore a dual-track approach combining project-based learning with ideological and political education.

In Summary, the blended learning effectively improves learning efficiency by combining online knowledge delivery with offline deep interaction. PBL uses real-world engineering problems and focuses on cultivating students' systematic thinking as well as complex problem-solving abilities. The integration of blended learning and PBL offers an effective pathway to overcome challenges in engineering practice-oriented education. This study adopts a dual-track approach centered on interdisciplinary subjects (Computer Organization Principles and Digital Logic Circuits) and project-based learning, in which incorporates industry resources to reform teaching models. This enables students to grasp the strategic significance of core technology self-reliance through experimental practice while simultaneously cultivating a spirit of craftsmanship and industrial responsibility.

2. The Curriculum Instructional Design

2.1. The Teaching Idea and Distribution of Class Hours

Adhering to the principle of "student-centered, project-based, and industry-oriented", we construct a trinity teaching system of "knowledge integration, ability progression, competency cultivation". The core goal is to break down curriculum barriers and achieve a three-dimensional leap from "theory to practice, campus to industry, and knowledge to competency", which can cultivate versatile people with complicate skill that meet the demands of "China's intelligent manufacturing".

The "Computer Organization Principles" is a core foundational course for Computer Science and Technology majors which focuses on revealing the structure, working principles, and coordination mechanisms of computer hardware systems. It combines theoretical depth with practical engineering applications. The course constructs a comprehensive knowledge framework through 40 class hours of theoretical teaching, and reinforces practical skills through 16 class hours of experimental teaching to help students establish a complete understanding of CPU-level and hardware system-level concepts and grasp the core idea of software-hardware collaboration.

2.2. Course Objectives and Lesson Objectives

"Principles of Computer Organization" is a core foundational course with strong theoretical, engineering and practical components. It plays a crucial role in the computer science curriculum system and services as a bridge between the preceding and the following courses. The course is closely connected with the prerequisite course "Digital Logic Circuit" and the subsequent course "Embedded System Development". It systematically teaches the basic principles of computer composition and internal working mechanisms which includes the introduction of computer systems, data representation, arithmetic methods and arithmetic units, storage systems, instruction systems, CPU design, bus technology, and input/output systems. Through studying this course, students will understand the composition and operating principles of computer components from the perspective of a designer, establish a complete machine concept at the CPU level and hardware system level, grasp the core idea of software and hardware collaboration, and lay a solid foundation for subsequent professional course. "Digital Logic Circuits" focuses on circuit design and signal timing primarily. These two courses exhibit a logical chain from low-level implementation to high-level application. They are effective supporters for implementing PBL teaching.

The PBL project of "single-bus CPU design" in the experimental system integrates cross-disciplinary knowledge points from "sequential circuit design of digital logic" to "implementation of CPU controller", and from "circuit optimization of digital logic" to "construction of CPU data path". In this way, it can form a complete problem-solving scenario from circuit to system. The course objectives and lesson objectives for "single-bus CPU design" of the course "Computer Organization Principles" are shown in Figure 1 and Figure 2 respectively.

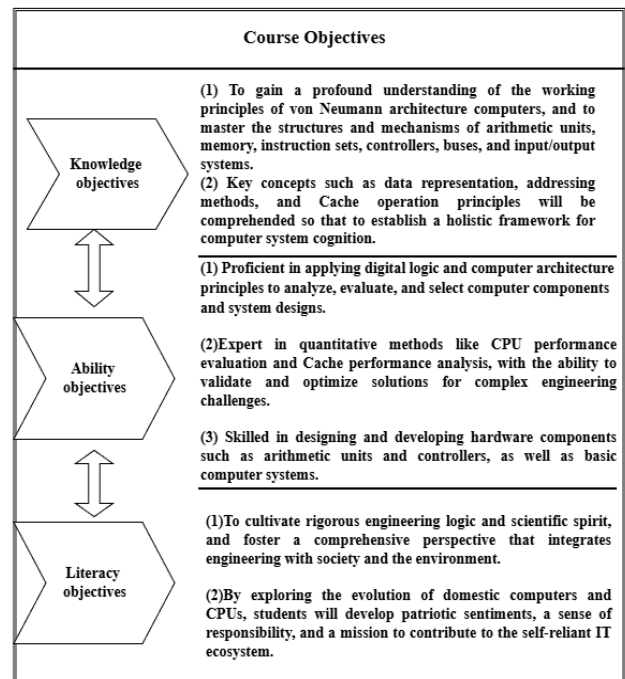


Figure 1. Course Objectives

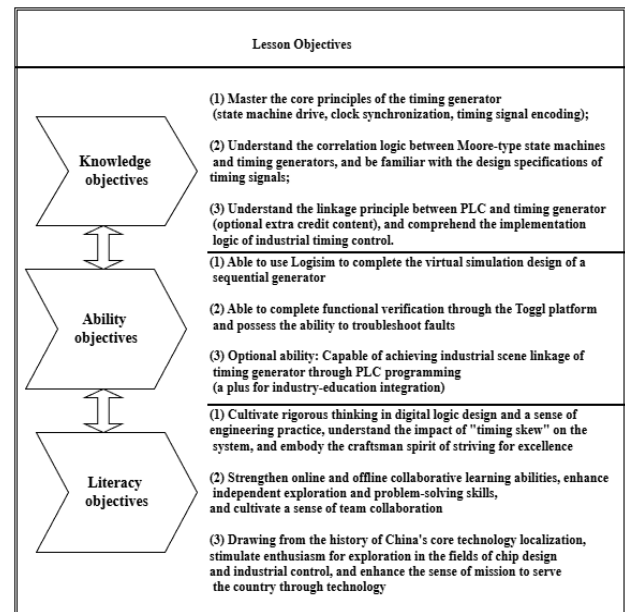


Figure 2. Lesson objectives

2.3. The Learning and Pain Point Analysis

This analysis is based on the data from the "Computer Organization Principles" course of approximately 180 sophomores who major in Computer Science and Technology. The course covers comprehensive information such as theoretical learning, experimental operations, and assessment performance. The overall academic atmosphere among students is positive with a high attendance rate and well classroom discipline. Over 95% of students are able to complete experimental tasks and assignments on time. However, there are significant individual differences which presents a distribution characteristic of "concentration in the middle and polarization at both ends". Students have acquired the foundational knowledge of prerequisite courses such as "Digital Logic Circuit". The distribution of students' mastery of knowledge points in assessment is shown in Table 1. It can be seen from the table that students make a relatively larger

proportion of errors in comprehensive application and engineering design.

Table 1. Distribution of students' mastery of knowledge points in assessment

| High Error Rate Knowledge Points | Error Rate | Corresponding Course Objectives | Difficulty Level |
|---|------------|--|---------------------------|
| CPI calculation and program performance evaluation | 64% | Knowledge objectives, Ability objectives | Comprehensive application |
| Control flow and data flow of instruction execution | 58% | Knowledge objectives, Ability objectives | Engineering design |
| Cache replacement algorithm | 49% | Knowledge objective | Principle understanding |
| Machine number conversion and data representation | 45% | Knowledge objective | Basic Application |
| Error detection code and parity check | 42% | Knowledge objective | Principle understanding |

Based on preliminary research data and reflections on course instruction, the key teaching challenges of this course are summarized as follows:

(1)Fragmented knowledge system: "Digital Logic Circuits" and "Computer Organization Principles" belong to two separate courses. Although the two courses have inherent connections in terms of knowledge points, their teaching content is independent and lacks coherence, which makes it difficult for students to establish a complete cognitive chain from "logical components" to "computer systems". Thus, isolated learning islands are formed.

(2)Disjointed learning and usage: The teaching focuses on theoretical lectures primarily with a preponderance of confirmatory experiments, and lacks engineering practice driven by real industrial scenarios. Although students are able to complete the established experimental steps, they lack core training in engineering problem oriented solution design and performance optimization. This leads to a mismatch between the learning content and the competency requirements of industrial positions.

(3)Weakness in quality: The integration of ideological and political education elements into courses is forced and have not been deeply integrated with teaching content such as hardware principles, experimental design, and system development. Also, the industry-education collaboration remains superficial. There is a lack of effective platforms to cultivate students' craftsmanship spirit and patriotic dedication to technology.

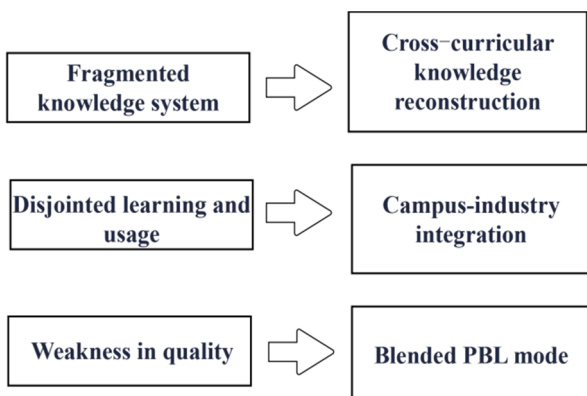


Figure 3. The solution framework for addressing pain points

To address three core pain points in teaching, This course has established a PBL blended teaching approach based on interdisciplinary subjects. This helps students transition from being knowledge acquirers to becoming application-oriented, skill-based, and innovative engineering composite talents. The solution framework for addressing pain points is shown in Figure3.

3. The Design and Process of the Course

3.1. The Core Concept of Blended Teaching

The entire teaching design adopts a cross-disciplinary PBL blended learning approach, guided by the ethos of industry-education integration and the spirit of master craftsmanship. It uses a closed-loop process encompassing "Before-class, During-class, and After-class" activities and integrates online platforms with offline practices to promote cross-curricular knowledge integration and skill development. The design process of PBL blended teaching based on interdisciplinary subjects is shown in Figure 4.

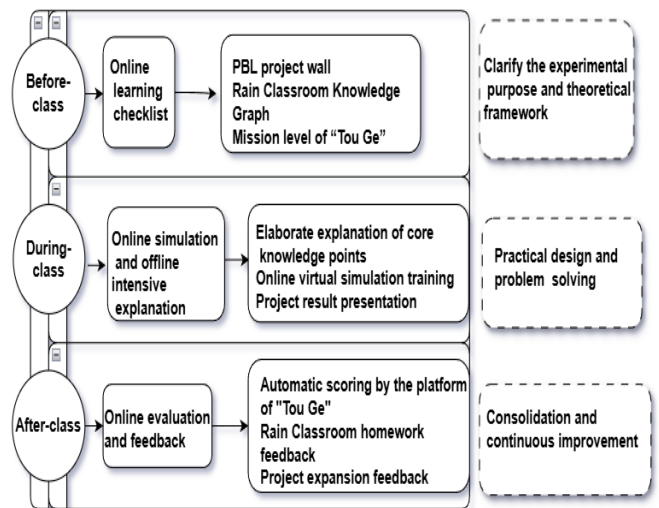


Figure 4. The design process of PBL blended teaching based on interdisciplinary subjects

This course includes both theoretical and practical teaching. We take the experimental teaching as an example in this article. The experimental teaching mainly includes the design of arithmetic units, memory, and CPU. In the experimental project of single-bus CPU design, we take the design of a timing generator as an example and the experimental teaching design is as shown in Table 2.

3.2. Cross-course Knowledge Reconstruction to Solve the Problem of "Knowledge Island"

Knowledge island refers to a state where knowledge lacks correlation, cannot circulate, or is concentrated in the hands of a few individuals and cannot be shared that results in learners having difficulty forming a systematic knowledge system and collaboration efficiency will be limited. The process of interdisciplinary course modules which can break down disciplinary boundaries and construct a cross-disciplinary knowledge system is also a process of cultivating systematic thinking, innovative thinking, and practical abilities. Traditional isolated teaching models often lead

learners to develop single-discipline thinking, and make it difficult to grasp the intrinsic connections of knowledge holistically.

Table 2. The experimental teaching design of timing generator

| Teaching stage | Online activities | Offline activities |
|--------------------------|--|---|
| Before-class preparation | (1) Through online learning checklist to Preview (e.g. Project Wall). 2. Through Rain Classroom to finish self-study. (e. g. knowledge graph) | 1. Group task division. |
| During-class | (1) Online simulation and debugging. (2) Troubleshooting for passing levels of Tou Ge platform. | (1) Detailed explanations of core knowledge points. (2) Hardware setup and joint debugging. (3) Group project progress meeting. |
| After-class Extension | (1) Feedback on project expansion. (2) Online peer review and Q&A. | (1) Achievement presentation and defense. (2) Ideological and Political Theme Seminar. |

By linking knowledge from digital logic circuits and computer organization principles, interdisciplinary modules guide learners to shift from a partial perspective to a system perspective, and teach them to analyze and solve problems comprehensively from underlying logic to macro-level architecture. The "Single-Bus CPU Design" experiment serves as the core project which can link the key concepts of "Digital Logic Circuits" and "Computer Organization Principles" to form a complete knowledge chain from underlying logic to system implementation. We analyzed the correlation between these two courses from three layers and the relationship between the two courses was presented in Table 3.

Table 3. The relationship between the two courses

| Knowledge layer | Digital Logic Circuit | Computer Organization Principles | Intersection of knowledge |
|-------------------|---|---|--|
| Base layer | Number system coding, logic algebra, sequential circuit | An overview of Computer System and Architecture | Hardware Logic is the Implementation Foundation of System Architecture |
| Core layer | Trigger, register, state machine | Instruction set, CPU composition, data path | Clock-driven CPU instruction cycle execution |
| Application layer | Design of Combination / Sequential Circuit | Storage system, I/O interface, bus technology | Circuit design supports the peripheral and CPU working together |

3.3. Deep Integration of Industry and Education: Bridging Campus and Industry

PLC is an electronic system device centered around a microprocessor for digital operation. It is specifically

designed for industrial field applications. It utilizes programmable memory to store operational instructions such as logical operations, sequence control, timing, and arithmetic operations. Through digital input and output interfaces, various communication modules or intelligent modules control various types of machinery or production processes. PLC is a dedicated industrial computer, and its hardware architecture fully corresponds to the composition of a computer which shown in Figure 5.

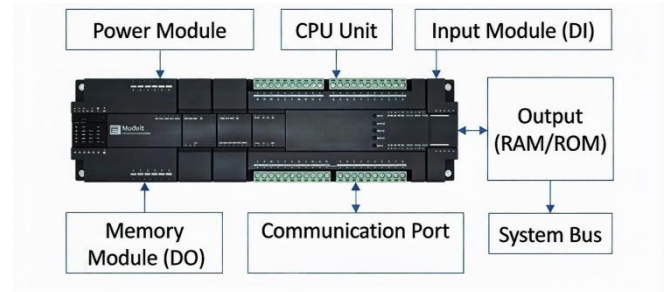


Figure 5. The hardware architecture of PLC

The correspondence between the internal structure of PLC and the composition of a computer is as follows which is shown as Figure 6:

- (1) The CPU module corresponds to the CPU of the computer that responsible for computation and control.
- (2) Input/Output (I/O) modules correspond to peripheral interfaces of computers such as GPIO, serial ports.
- (3) The memory corresponds to the computer's internal memory in which the system program memory is ROM, and the user program memory is RAM.
- (4) The power supply corresponds to the power interface of the computer.

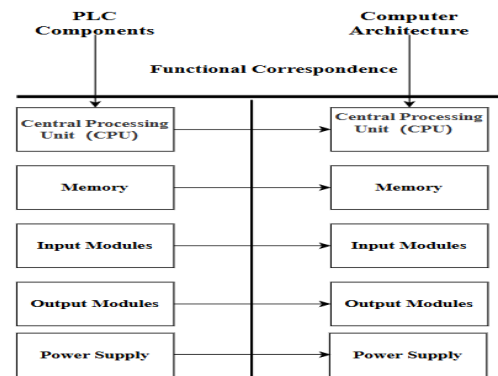


Figure 6. The correspondence between the PLC Components and Computer Architecture

PLC shares deep homology with the fundamental architecture of computer organization principles through their core sequential control logic. The state machine design of PLC replicates the FSM (Finite State Machine) timing logic of CPU controllers. Taking the "single-bus CPU design" as an example, it illustrates how PLC sequential control corresponds to execution flows of timing logic circuits and computer instruction. PLC sequential control is equivalent to timing logic circuits such as FSM in digital circuits. The term "state" refers to register values in circuits, while "finite" indicates limited state numbers. For instance, the sequential control of car moving from point A to B to C in PLC corresponds to a digital circuit state transition diagram: "state 1 (A) → state 2 (B) → state 3 (C)". Current states are stored in flip-flops according to input signals to trigger state

transitions.

By collaborating with leading domestic industrial control enterprises to introduce real industrial requirements such as timing control of industrial production line and integration of domestic PLC with CPU to push experimental tasks upgrade from verification to engineering-oriented. The course plan integrates core enterprise technologies including industrial CPU control logic into the curriculum module to align with job competency requirements for embedded development and industrial control positions. Meanwhile, the curriculum group also plans to invite industrial engineers to participate in curriculum design, provides realistic requirement documents, industry standards and conducts online and offline lectures

4. Hybrid PBL Experimental Teaching Model

4.1. PBL Blended Learning Model

PBL has demonstrated significant advantages in course instruction, particularly in engineering education such as computer science. It has become a crucial teaching methodology for cultivating students' capabilities in solving complex engineering problems. However, there exists some problems such as difficulty in sustaining learning motivation. To address these challenges, this project proposes a hybrid PBL teaching process through of AI technology and Interdisciplinary courses which aims to establish a more supportive and interactive blended learning environment that delivers personalized learning experiences centered on students. From the student perspective, the core PBL process typically consists of five steps which is shown in Figure 7.

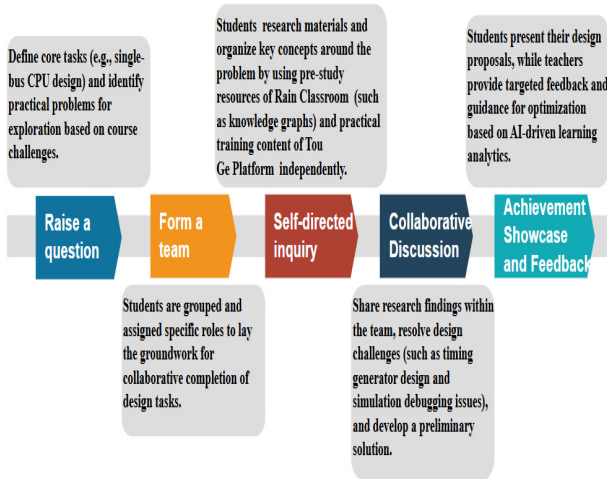


Figure 7. The core PBL process

In the implementation of interdisciplinary course modules, PBL serves as the core vehicle for bridging theoretical knowledge with practical application and deepening multidisciplinary integration. As organizers of PBL, instructors play a pivotal role throughout the entire project which influences both the effectiveness of PBL instruction and the depth of interdisciplinary knowledge integration. Given the characteristics of courses in "Digital Logic Circuits" and "Computer Organization Principles", instructors can focus on the following key tasks:

(1) Teachers can design corresponding PBL components aligned with instructional objectives that can displayed through project walls typically. The project wall uses single-bus CPU design is shown in Figure 8.

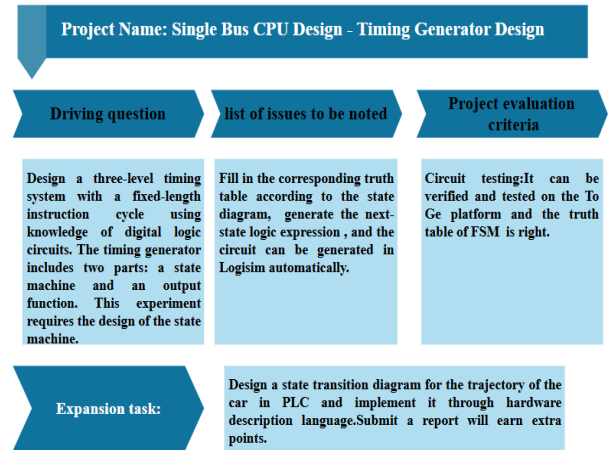


Figure 8. The project wall of single-bus CPU design

(2) Teachers should guide students in independent inquiry to stimulate their initiative in learning. PBL emphasizes learner-centered approaches, requires teachers to abandon rote teaching and transition into facilitators who guide learners to actively break down project tasks and explore solution pathways. During the project initiation phase, teachers can use questioning and case analysis to help learners identify core challenges, required knowledge modules, and connect relevant concepts from digital logic circuits and computer architecture. Therefore, the learner's knowledge framework can be established.

(3) Teachers should organize collaborative exchanges among students to overcome challenges in interdisciplinary learning. Interdisciplinary PBL projects often require learners to divide tasks and leverage complementary strengths. Teachers should assume the role of facilitators, guide learners to form appropriate groups and define roles within each team clearly to ensure well-defined responsibilities. Simultaneously, they should use AI platforms to organize group discussions and share learning outcomes. Additionally, they should monitor each learner's engagement level and provide targeted guidance to those with lower participation to ensure the group's learning efficiency and quality.

(4) Teachers can use AI technology to provide students with continuous support throughout the learning process and personalized assistance. During PBL implementation, they will encounter diverse individual challenges that range from specific technical hurdles like digital logic circuit design and timing control to theoretical difficulties such as understanding hardware architecture and instruction execution logic in computer organization principles, as well as practical issues like project planning and collaborative task allocation. The use of AI teaching assistants can make projects smoother and more efficient.

(5) Teachers need provide scientific feedback on project outcomes to deepen students' knowledge and enhance their skills. The core of PBL assessment lies in process evaluation and comprehensive evaluation. Thus, it is important for teachers to establish a multifaceted evaluation system that considers both the final outcome of the project and learners' investigative processes, collaborative abilities, innovative thinking, and problem-solving skills throughout project implementation. The assessments should include teacher evaluations, member evaluations, and group self-assessments to ensure objectivity and comprehensiveness. Teachers need to inform students of the evaluation results.

4.2. PBL Literacy Oriented Design

In the implementation process, the PBL model plays a pivotal role, in which the literacy education design integrated throughout the entire PBL implementation cycle. During the project design phase, by explaining the development history of Dragon architecture and PLC technology can help students grasp the importance of achieving self-reliance in core technologies. During the implementation, when learners encounter challenges like failed logic circuit designs or CPU module coordination issues, they are encouraged to overcome them and establish a rigorous scientific attitude. During the assessment phase, ideological and political performance is integrated into a multi-dimensional evaluation system. By combining the development history and exemplary cases in the field of computer hardware in China, learners can establish correct professional values and patriotism. In the extension phase, project outcomes can be introduced into real-world industrial scenarios so that to achieve a trinity of knowledge acquisition, skill enhancement, and value guidance.

4.3. Diversified Evaluation System

Table 4. The distribution indicators for regular performance assessment

| Number | Assessment type | Score percentage | Remarks |
|--------|---|------------------|--|
| 1 | Online test results | 20% | Including unit tests, online viewing progress, and online interactions |
| 2 | Online process score | 20% | Including Rain Classroom grades, assignments, and forums |
| 3 | Offline performance | 20% | Including attendance, assignments, and classroom performance |
| 4 | Experiment Results (Virtual Simulation) | 30% | Including the completion status of experiments and the quality of experimental reports |
| 5 | Value-added assessment (virtual to practical) | 10% | Emphasize the innovation and design of experiments |

Diversified Evaluation System mainly focuses on process evaluation supplemented by summary evaluation which can track learners' performance throughout the implementation of the project. In terms of evaluation subjects, the course achieves an organic combination of teacher evaluations, member evaluations, and group self-assessments among team members, which formed a comprehensive evaluation loop. The Teacher evaluation focuses on professional standardization and ideological and political orientation which emphasis on evaluating the professional standards of project outcomes, the scientific nature of the exploration process, and the manifestation of ideological and political literacy. Team member evaluation focuses on individual contribution, member's participation, sense of responsibility, and professional ability that based on code writing, simulation testing, communication and collaboration. Group self-assessment focuses on the effectiveness of team collaboration, where the group collectively identifies the strengths and weaknesses in project implementation, reflects on the experiences and lessons learned from division of labor,

collaboration, and problem-solving.

The course employs a three-dimensional evaluation framework which integrate theory, process and project. Online assessments serve as theoretical evaluations, while online and offline process evaluations focus on procedural assessment, and ability enhancement is reflected in project-based experiments. The final grade focuses on assessing students' understanding of the overall working principles of computer systems, as well as their abilities in engineering analysis and design. The distribution indicators for regular performance assessment are shown in Table 4.

4.4. Experimental Outcomes and Student Feedback

By implementing this teaching method, students' abilities and qualities have been improved. The effectiveness data for this study comes from the experimental course of the "Single Bus CPU Design - Timing Generator Design" chapter in "Computer Organization Principles", with a sample of 100 students from 2 classes (50 students each). The analysis of practical effects is shown in Figure 9. Through practice, it can be found that students' efficiency in solving complex problems, classroom participation rate, ideological and political awareness achievement rate, and industry interest stimulation rate have all been improved, effectively solving pain points in teaching. This case has strong scalability. Firstly, it is suitable for basic courses in engineering majors such as electronic technology and embedded development, and the logic of cross course integration and ideological and political integration can be directly transferred. Secondly, it relies on conventional AI tools such as Rain Classroom, which does not require complex hardware and is easy to implement in universities. Thirdly, the indicator system is quantifiable and clear that provides a standardized reference paradigm for teaching reform of similar courses.

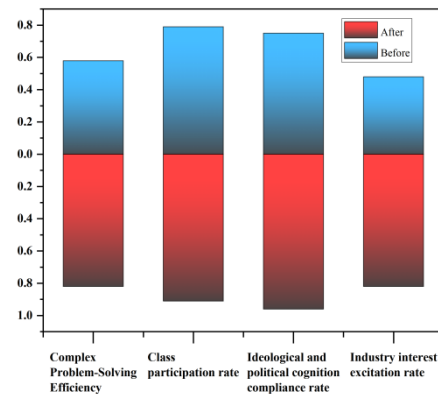


Figure 9. The analysis of practical effects

We also conducted a questionnaire survey on the 100 students mentioned above, and randomly selected 48 valid questionnaires from them. 90% of students believe that cross-disciplinary projects have helped them grasp the fundamental principles of hardware design and overcome the knowledge island to some extent. 87% of students indicate that industrial scenario tasks are more challenging. 82% of students agree that the combination of ideological and political cases with industrial cases is reasonable, which enhances their learning motivation. However, there are also some negative feedback. 18% of students reported that cross-disciplinary knowledge was too challenge to understand and it is difficult to keep up with the progress in the early stage. 15% of students believe

that there is a significant difference in the logic of online simulation and offline hardware operation, and it is difficult to transfer learning. 12% of students pointed out that the industrial side lacks sufficient fault scenario settings, and its ability to address industrial-level issues still needs improvement.

4.5. Optimization Measures

In response to the negative feedback mentioned above, combined with the characteristics of interdisciplinary PBL projects, this course can adopt targeted optimization measures to help students steadily improve their comprehensive abilities. The course will conduct a layered task system such as the single bus CPU design which can be divided into three gradients: foundation layer, improvement layer, and innovation layer. In addition, the course will also optimize the PBL practical process by combining online simulation with practical coding, and jointly building an industry training case library with enterprises. One important thing is that the course will continue to integrate AI technology and further strengthen the deep integration of AI and interdisciplinary teaching. In layered tasks, AI can accurately depicts students' knowledge base, dynamically pushes adapted group and digital logic learning resources and task gradients. In third-order practice, AI simulation tools can achieve precise connection between online virtual operations and offline hardware operations, real-time error correction and generate personalized practical guidance. In industry docking, AI can explore industrial level fault scenarios and assists in fault investigation.

5. Conclusion

In summary, in order to build a multidisciplinary knowledge system that integrates computer composition principles and digital logic circuits to solve pain points in teaching, it is necessary to integrate PBL and course ideological and political education based on interdisciplinary course. The interdisciplinary curriculum module solves the problem of knowledge silos and achieves organic connection of knowledge. The PBL model stimulates students' independent exploration and collaboration abilities through practical projects, which helps them apply theoretical knowledge to practical situations. The full integration of ideological and political education into the curriculum has achieved a resonance between value guidance and professional training. The diversified evaluation system takes into account both the process and results, as well as the professional and ideological aspects. These measures all contribute to promote the improvement of students' comprehensive literacy. In response to the three major issues raised by students, optimization measures such as layered tasks, three-level practice, and industry integration have further enhanced the adaptability of PBL. Through the

combination of the above links, students can not only strengthen their professional foundation and enhance their practical and innovative abilities, but also cultivate their patriotism, craftsmanship spirit, and sense of responsibility, which is beneficial to cultivate compound and innovative computer professionals, and provide practical references for interdisciplinary curriculum construction and teaching reform.

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