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Exploration and Practice of "PLC Principles and Interface Technology" Course Reform in the Context of Integration of Science, Education, and Industry

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Abstract: In the context of deep integration between science, education, and industry, the teaching reform of the "PLC Principles and Interface Technology" course focuses on collaborative innovation between industry needs and education. Addressing issues such as the disconnect between theory and practice in traditional teaching, lagging technology updates, and low matching with industry needs, a dual-track teaching model combining "project-driven learning + real-life cases" is established, incorporating actual engineering cases from enterprises. Through the industry-education integration platform, modular teaching resources are developed in collaboration with enterprise engineers, strengthening core skill training in PLC programming, inverter debugging, and other aspects. Simultaneously, ideological and political elements are integrated into the curriculum to cultivate students' craftsmanship spirit of excellence. Practice has shown that the reform significantly enhances students' engineering capabilities and comprehensive qualities. It has also greatly improved enterprise satisfaction with graduates and the depth of cooperation between schools and enterprises, effectively promoting the coordinated development of teaching, scientific research, and industry.

1. Introduction

The wave of Industry 4.0 has propelled smart manufacturing to become the core trend in global manufacturing. Programmable Logic Controllers (PLCs), with their high flexibility, reliability, and robust control capabilities, have emerged as the core supporting equipment in the field of industrial automation[1]. They are widely applied in diverse sectors such as machinery manufacturing, automobile production, and new energy, playing an irreplaceable role in scenarios like automated processing, production collaboration, equipment control, and energy monitoring. As the degree of industrial automation continues to deepen and PLC application scenarios expand, the demand for relevant technical talents is experiencing explosive growth[2].

"PLC Principles and Interface Technology" serves as a core course in majors such as machinery and automation, and is a key vehicle for cultivating students' PLC application abilities. It is not only the cornerstone for mastering the core technology of industrial automation, but also a bridge connecting theory and engineering practice. Through course learning, students can systematically grasp core knowledge such as PLC working principles and programming methods, and develop design and development abilities for industrial control systems. However, there are three prominent issues with the traditional teaching model: First, there is a disconnect between theory and practice, and "spoon-feeding" teaching methods lead to a lack of practical training for students, making it difficult for them to apply knowledge in real-world projects. Second, technological updates lag behind, and textbooks and teaching content are outdated, failing to cover the advanced functions of new PLCs and lagging behind market demands. Third, there is low industry alignment, weak cooperation between schools and enterprises, and teaching content that does not align with enterprise job standards, increasing the cost of secondary training for enterprises. These issues lead to insufficient employment competitiveness among graduates, which not only restricts students' career development but also increases the burden on enterprises[3].

Against this backdrop, leveraging the opportunity presented by the deep integration of science, education, and industry, exploring the path of curriculum reform for "PLC Principles and Interface Technology" has become crucial for enhancing teaching quality and cultivating high-quality technical talents suitable for the industry. Curriculum reform must closely align with industry needs, incorporate enterprise cases, transform scientific research resources, and strengthen practical teaching. This allows students to engage with cutting-edge technologies and practical problems, comprehensively enhancing their problem-solving abilities and professional qualities, and providing talent support for the development of Industry 4.0 and intelligent manufacturing.

2. Problems with traditional teaching models

In the current teaching process of "PLC Principles and Interface Technology", the traditional teaching mode is like an invisible shackle, severely restricting the improvement of teaching effectiveness and the cultivation of students' abilities. The existing problems exhibit systematic and multidimensional characteristics, which are not only reflected in the internal imbalance of teaching links but also extend to the disconnection with external industry demands, posing a great obstacle to cultivating high-quality technical and skilled talents who can adapt to the development needs of the times, as shown in Figure 1. These problems are mainly manifested in the following three points:

2.1 The disconnection between theory and practice

In the traditional teaching of "PLC Principles and Interface Technology", the imbalance between theory and practice is severe, hindering the improvement of students' comprehensive abilities and the optimization of teaching quality. Traditional teaching emphasizes theory over practice, with obvious drawbacks. In terms of teaching arrangement, teachers dominate the classroom, adopting a "lecture-based" approach, spending a lot of time explaining PLC principles, instruction systems, and other content, while students passively take notes and memorize, lacking active thinking and exploration. The classroom atmosphere is dull, eroding students' interest and enthusiasm for learning. In terms of knowledge presentation, the theory is abstract and obscure. PLC principles involve complex electronic circuits, logic control knowledge, and numerous instruction system codes and parameter settings, making it difficult for students to understand[4]. For example, when explaining timer instructions without combining them with actual industrial control scenarios, students find it difficult to understand their functions. In practical applications, students frequently encounter problems. Due to a lack of practical operation, they are not familiar with PLC equipment operation and do not know how to connect theory with actual equipment. In actual projects, they may encounter connection failures, program debugging errors, and other issues, but they do not know how to troubleshoot and solve them. For example, in a motor start-stop control project, students may master the theory but make wiring errors, causing the motor to fail to start, and blindly debug the program due to a lack of in-depth understanding of instructions. The disconnect between theory and practice leaves students at a loss when facing actual projects, unable to transform theory into operational skills, affecting learning outcomes and career development. It also leads students to understand knowledge only at a superficial level, making it difficult for them to form a systematic knowledge system, appreciate the practicality of knowledge, and develop a sense of boredom, reducing their learning enthusiasm. Therefore, in the teaching of "PLC Principles and Interface Technology", it is necessary to strengthen the integration of theory and practice, provide students with more practical operation opportunities, and allow students to deepen their understanding of theoretical knowledge through practice, improving their ability to solve practical problems.

2.2 Technical updates lag behind

With the rapid development of technology today, PLC technology, as the core support of industrial automation, is undergoing rapid iteration and upgrading. New PLC products are constantly emerging, with increasingly powerful and diverse functions, playing a crucial role in various aspects of industrial production. At the hardware level, new PLCs have made significant progress. In terms of processing speed, traditional PLCs are limited by chips and other factors, resulting in slow data processing and instruction execution, making it difficult to meet the needs of high-real-time complex scenarios; new PLCs adopt advanced processors, enhancing computing power, enabling rapid data processing and analysis, such as real-time monitoring and adjustment in precision assembly lines for electronic products. In terms of storage capacity, as industrial production scales expand and processes become more complex, data volume increases dramatically, while traditional PLCs have limited storage; new PLCs are equipped with high-capacity storage devices, capable of storing massive amounts of data and supporting complex programs, providing guarantees for intelligent management, such as long-term data storage in monitoring systems for large chemical enterprises. In terms of communication capabilities, modern industry emphasizes equipment interconnection and collaboration. New PLCs support multiple communication protocols, enabling seamless docking and data exchange with different devices, achieving remote monitoring and centralized control, such as aggregating data to a headquarters management platform for cross-regional industrial production clusters. However, traditional textbooks and teaching content on "PLC Principles and Interface Technology" struggle to keep up with technological updates. Textbooks are mostly based on technologies and products from many years ago, with cases revolving around traditional simple industrial control scenarios, and PLC models and functions are outdated. Teachers mostly follow the framework of textbooks, only briefly mentioning advanced functions of new PLCs such as high-speed counting, lacking in-depth teaching and practical guidance. This results in a significant gap between what students learn and the actual needs of enterprises. After graduation, students are at a loss when facing new PLC equipment and advanced industrial control systems, and enterprises need to spend a lot of time and effort on secondary training for graduates, increasing costs and affecting production efficiency and competitiveness. For example, when a certain automobile manufacturing enterprise introduced a new PLC automated welding production line, the recruited graduates were unable to complete debugging and troubleshooting independently due to their lack of exposure, and required several months of training to become basically competent. Therefore, in order to enable students to adapt to enterprise needs and enhance their employment competitiveness, it is necessary to timely update and optimize the teaching content of "PLC Principles and Interface Technology", incorporate new PLC technologies and functions into the teaching system, strengthen practical teaching, and narrow the gap between what students learn and actual needs.

2.3 Low matching degree with industrial demand

The traditional teaching model generally suffers from a disconnect with the actual operational scenarios of enterprises, lacking a deep and stable mechanism for school-enterprise cooperation. In terms of curriculum design, universities primarily focus on imparting theoretical knowledge, lagging behind in understanding cutting-edge industry technologies, practical job standards, and core business processes of enterprises. There may even be information asymmetry, leading to significant deviations between the training system and the real needs of the industry. During their time in school, students are mostly exposed to standardized and idealized simulation scenarios, lacking practice in dealing with complex real-world problems. Their core skills do not match the job requirements of enterprises—such as the application of digital tools, process optimization capabilities, and cross-departmental collaboration experience that enterprises urgently need—which are often weak links in traditional teaching. This directly leads to the situation where, even if students possess basic theoretical knowledge, they find it difficult to quickly adapt to their job roles upon graduation. Enterprises have to invest a lot of manpower, resources, and time to carry out systematic secondary training tailored to job requirements, which not only prolongs the employee onboarding period but also increases additional labor costs such as recruitment and training, reducing the efficiency of talent cultivation for enterprises[5]. At the same time, this mismatch between supply and demand also leaves students facing the dilemma of "graduation equals unemployment" or "starting a new learning journey upon employment", exacerbating the structural contradictions in the job market.

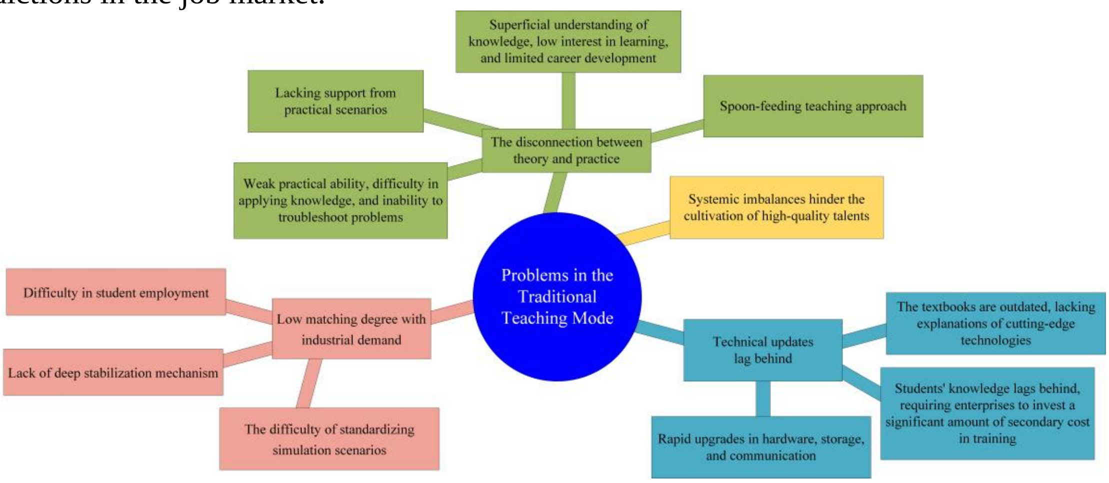

Figure 1: Problems in the Traditional Teaching Mode

3. Exploration and Practice of Curriculum Reform

Faced with numerous issues in traditional teaching of "PLC Principles and Interface

Technology," such as the disconnect between theory and practice, lagging technology updates, and low alignment with industry needs, this course actively engages in curriculum reform to genuinely enhance teaching quality and bolster students' professional competencies and employability. It explores and practices in various aspects, striving to construct an effective teaching model that aligns with practical needs.

3.1 Establish a dual-track teaching model of "project-driven + real cases"

Under the traditional teaching model, there is a serious disconnect between theory and practice in the PLC Principles and Interface Technology course. In the classroom, teachers focus on theoretical explanations, adopting a "spoon-feeding" teaching method, where students passively receive information and lack opportunities for active thinking and practical operation. As a result, students' grasp of core skills remains at the textbook level, making it difficult for them to understand practical application scenarios and operational essentials. After graduation, students often feel at a loss when facing actual projects in enterprises, unable to transform theory into practical operational skills. This requires secondary training by enterprises, increasing labor costs. To address this challenge, the course has constructed a dual-track teaching model of "project-driven + real case studies". This model is guided by actual projects and supported by real case studies, integrating theory with practice, allowing students to "learn by doing and do by learning". The course team has collaborated with several well-known enterprises to conduct in-depth research and collect a large number of representative real-world engineering cases, covering multiple fields such as automated production line control, which align with the actual needs of enterprises. For example, the case study of the automation transformation of an automobile manufacturing enterprise's production line allows students to intuitively understand the application of PLC technology. The course carefully sets up challenging projects such as "automated production line control", where students are divided into groups to simulate enterprise project teams and complete the entire project process. During the project design phase, students apply theory to conduct demand analysis, scheme design, and feasibility assessment, selecting equipment and determining the plan. In the programming phase, they use PLC programming software to write programs and optimize debugging. In the debugging phase, they download the programs to the equipment and solve various problems that may arise. Participating in projects exercises students' practical abilities, enabling them to master core skill operation methods, and also cultivates team collaboration and communication skills. This teaching model provides students with a real and close-to-engineering learning environment, effectively solving the problem of the disconnect between theory and practice, and laying the foundation for students' career development.

3.2 Jointly develop modular teaching resources with enterprise engineers

With the rapid development of technology and the ever-changing industrial automation technology, PLC-related technologies continue to iterate. However, traditional teaching resources have a long update cycle and lag behind in content, causing a disconnect between what students learn and the actual needs of enterprises. This leads to the need for secondary training after entering the enterprise, increasing the human cost for enterprises and affecting the starting point of students' career development. To address the issue of lagging technology updates, this course leverages the industry-education integration platform to collaborate deeply with enterprise engineers to jointly develop modular teaching resources. The industry-education integration platform serves as a communication bridge between the course and enterprises. Schools have professional teachers and rich teaching experience, while enterprises grasp the latest technological trends and actual production needs. Both parties regularly communicate to clarify the direction and goals of teaching resource development. During development, the course team and enterprise engineers break down the course content into multiple independent and targeted modules based on the actual needs and technological trends of enterprises, such as PLC fundamentals, communication, motion control modules, etc. Each module focuses on a specific technical field and application scenario, with clear learning objectives and teaching priorities.

PLC Basic Module: Targeted at beginners, it covers fundamental concepts, principles, hardware structure, and programming languages. Corporate engineers explain theories through practical cases, such as the start-stop control of factory production line equipment. Case studies are selected from real-world corporate projects, such as automated warehouse goods storage and retrieval. Experimental operations provide advanced equipment and environments, such as programming to control traffic lights.

Communication module: Cultivate communication skills between PLC and other devices. Corporate engineers introduce mainstream communication protocols and methods, such as Modbus, Profibus, Ethernet, etc., and demonstrate communication implementation through case studies, such as PLC communication with temperature sensors. Arrange experimental operations, such as building a communication network.

Motion control module: An in-depth explanation of the application of PLC in the field of motion control. Corporate engineers introduce control algorithms, programming, and debugging techniques based on project experience, such as robot trajectory planning control. Experimental operations provide a motion control platform for students to control devices such as stepper motors and servo motors.

The curriculum team has established a mechanism for regularly updating teaching content with enterprise engineers, paying attention to industry dynamics and changes in enterprise needs, and promptly adjusting and updating content, such as incorporating new PLC models and communication protocols, optimizing and improving based on enterprise feedback, to ensure that the teaching content is practical and targeted. By jointly developing modular teaching resources, the curriculum has solved the problem of lagging technology updates, providing students with rich, practical, and cutting-edge learning content, enhancing students' learning interest and effectiveness, and laying a solid foundation for their career development.

3.3 Strengthen core skill training

This course closely aligns with the job requirements of industrial automation positions, focusing on PLC programming and inverter debugging as core skill development points. It utilizes a "theory + practical operation + simulation" teaching model to strengthen skill training. The course increases the proportion of experimental and practical training projects to no less than 40%, ensuring that students have ample opportunities for practice. PLC programming training ranges from basic to comprehensive applications, with students independently completing the entire process to master practical skills. Inverter debugging is achieved through modular training, allowing students to become familiar with parameter configuration, master debugging methods, and enhance their ability to handle complex working conditions. The course introduces a virtual simulation platform to create a virtual environment consistent with real equipment, reducing operational risks and helping students intuitively understand equipment principles. The combination of virtual simulation and real machine training forms a closed-loop training system, solidifying skills. In addition, the course establishes an assessment system to ensure that students meet the skill requirements of corporate positions and are well prepared for employment or further education.

3.4 Integrate ideological and political elements into the curriculum

With "skill cultivation+value guidance" as its core, this course deeply integrates ideological and political education with the content of industrial automation major, achieving the three-in-one teaching goal of "knowledge impartation, skill training, and quality cultivation", and helping students grow into high-quality technical talents with both professional competence and professional responsibility.

3.4.1 Anchor professional values and cultivate a deep sense of national sentiment

The course combines the exploration of ideological and political connotations in industry application scenarios of PLC and frequency converter technology, introducing their core roles in fields such as intelligent manufacturing and high-speed rail operation and maintenance through thematic sharing and case analysis, allowing students to experience the supporting value of technology for industrial upgrading and national industrial modernization. It also introduces the development history and technological breakthrough cases of industrial automation in China, tells the story of domestic PLC technology progress, stimulates students' national pride and sense of mission, guides them to combine personal development with national industrial needs, and establishes the ideal and belief of serving an industrial powerhouse.

3.4.2 Focus on the spirit of craftsmanship and hone professional qualities

The course breaks away from traditional ideological and political education models, integrating the spirit of craftsmanship into practical teaching. It not only shares stories of engineers overcoming challenges, allowing students to understand that the spirit of craftsmanship manifests in the details, but also sets assessment dimensions in practical training, requiring rigorous programming and perfect debugging. Furthermore, it guides students to learn professional ethics from practical training problems and cultivates their abilities to solve problems and continuously improve.

3.4.3 Strengthen professional ethics and cultivate a sense of responsibility

The course combines the characteristics of industrial automation positions and integrates education on professional ethics and responsibility awareness. By analyzing safety accident cases, it emphasizes professional norms and guides students to establish the concept of "safety first, quality supreme". Comprehensive practical training projects cultivate team collaboration skills, and project acceptance processes refine professional ethics. Additionally, invited corporate leaders conduct online lectures to help students establish professional values, laying the foundation for workplace integration and long-term development.

4. Reform Achievements

After implementing a series of comprehensive and in-depth curriculum reform measures, students' engineering practical abilities and comprehensive qualities have been significantly improved, as demonstrated by the following specific manifestations:

The reform of the teaching system centers on "empowering through practical operation and cultivating talents comprehensively", establishing a full-chain model of "theoretical foundation - simulation preview - real machine practical operation - project review", promoting the improvement of students' engineering practical ability and comprehensive literacy. Students' core skills are no longer limited to the basics, and they can independently complete comprehensive projects in industrial scenarios, such as tasks related to production line material handling systems. Excellent students can also optimize programs in a modularized manner to enhance system performance.

In terms of comprehensive literacy cultivation, the project-based teaching model allows students to deeply engage in team collaboration, from task division, scheme discussion to problem solving, effectively honing their communication, expression, and overall coordination abilities. The integration of ideological and political education into the curriculum has strengthened students' sense of responsibility. When program bugs or debugging errors occur during practical training, the proportion of students proactively reviewing the reasons, taking responsibility, and optimizing the scheme has increased by 60% compared to before the reform.

According to a sample survey conducted by the curriculum team, 89% of students expressed "very satisfied" with the teaching system after the reform, an increase of 42 percentage points compared to before the reform; students generally gave feedback that "the practical training projects are aligned with the actual needs of enterprises, and they can be applied immediately after completion" and "they learned to listen and tolerate in team cooperation".

5. Conclusion and Outlook

In the context of the deep integration of science, education, and industry, we have conducted reform exploration and practice for the course "PLC Principles and Interface Technology". By constructing a dual-track teaching model of "project-driven + real cases", collaborating with enterprise engineers to develop modular teaching resources, strengthening core skill training, and integrating ideological and political elements into the curriculum, we have significantly improved students' engineering practical abilities and comprehensive qualities, expanded the depth and breadth of school-enterprise cooperation, and enhanced the efficiency of teachers in transforming scientific research achievements into teaching resources. In the future, we will continue to deepen curriculum reform, strengthen cooperation with enterprises, and continuously improve the teaching system and teaching methods, contributing to the cultivation of more high-quality technical and skilled talents.

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