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Research on the Development and Application of Enterprise Case Resources in the Course "Smart Electrical Appliance Communication Technology"

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Abstract: In the context of the in-depth implementation of the "Double High Plan" and the digital transformation of vocational education, the construction of enterprise case resources has emerged as a critical breakthrough for reforming course teaching. It is imperative to address the challenge posed by the fragmented nature of traditional resources. This paper focuses on the cutting-edge course "Intelligent Electrical Appliance Communication Technology" within the equipment manufacturing domain as a case study. A three-dimensional resource construction model is proposed, characterized by "deep integration of industry and education - multi-dimensional transformation of cases - establishment of a practical ecosystem." The paper systematically elucidates the structured development pathway for enterprise cases, the teaching implementation strategy under the CDIO paradigm, and the innovative practice of integrating "positions, courses, competitions, and certifications." Research findings indicate that a case resource system grounded in real engineering scenarios can significantly enhance students' technical application capabilities and professional competencies, offering replicable practical models for the reform of engineering courses in higher vocational colleges.

Keywords: Intelligent Electrical Appliances; CDIO; Integration of Posts Courses Competitions and Certificates; Enterprise Case.

1. Introduction

Driven by the "Manufacturing Power Strategy" and the "Implementation Plan for the Action to Empower and Upgrade the Integration of Industry and Education in Vocational Education (2023 - 2025)", intelligent electrical appliance technology, as the core support for the upgrading of the equipment manufacturing industry, puts forward new requirements of "dual improvement of technical application ability and engineering qualities" for talent cultivation in vocational colleges.

The "Intelligent Electrical Appliance Communication Technology" course is a highly practical new technology application course for electrical majors. It serves the equipment manufacturing industry and the electrical industry, targets the position of professional engineers for the application and development technology of intelligent electrical appliance products, and cultivates students' professional abilities in the application of intelligent electrical appliances, the thinking methods of analyzing and solving practical problems, the values of patriotism and dedication, and the craftsmanship of striving for excellence. The course focuses on the engineering practice of intelligent electrical appliance communication technology. Its teaching reform needs to break through the traditional "fragmented knowledge teaching" model and construct an educational system of "immersive real scenarios - cultivation of engineering thinking - progressive innovation ability". To help students master the knowledge and skill points of this course more quickly, a supporting teaching resource library for the course has been built. The resource library is rich in materials, including enterprise cases, short videos, virtual simulations, etc. During the construction of the resource library, due to the close cooperation between schools and enterprises, relevant enterprises continuously integrate actual engineering projects into the cases. The constructed resources such as enterprise cases are highly practical and applicable, and students, teachers, and enterprise personnel have benefited from these cases.

This research relies on the "Motor and Electrical Appliance Technology" Double High professional group of Wenzhou Vocational and Technical College and collaborates with industry leading enterprises such as ABB. Through the dual development of schools and enterprises, the transformation of case teaching, and the reconstruction of the CDIO model [1-3], an enterprise case resource library with industry foresight has been created. As of 2025, the resource library has included more than 20 typical engineering cases, covering fields such as intelligent power distribution and distribution automation, forming a trinity resource system of "teaching cases - virtual simulations - skill work orders". It has cumulatively supported more than 800 hours of integrated theory and practice teaching [4-6], and the one-time passing rate of students' professional ability certification exams has increased by more than 20%.

2. The Three-Dimensional Construction Model of Enterprise Case Resource Construction

2.1. The "Four - Dimensional Standard" System for Case Selection

Enterprise cases need to follow the four - dimensional standards of teaching adaptability, technical advancement, scene authenticity, and ability coverage. Teaching adaptability is demonstrated by the precise mapping with 12 core knowledge points in the curriculum standard (such as Modbus protocol, FBD programming, etc.). The coincidence

degree between the case tasks and the typical work processes of the professional position (intelligent electrical appliance technician) is ⩾ 90%. Technical advancement is reflected in the fact that the course preferentially selects new technology application projects such as the WinCS control system and the industrial energy efficiency management platform. For example, a university's power distribution upgrade and transformation project. Scene authenticity is demonstrated by the fact that the content system of the course project directly comes from enterprise engineering projects and includes complete technical documents [7-9], such as configuration files, electrical schematic diagrams, construction drawings, etc. Ability coverage means that a single case needs to carry out the training of more than 3 ability modules. For example, a pumping station intelligent transformation project covers the whole - process skills of "hardware configuration - communication debugging - system joint debugging".

2.2. The "Dual - Element Collaboration" Mechanism for Resource Development

Table 1. Design of Capability Modules

Position Competency Module	Teaching Project	Class Hour
Basic application capabilities of the WinCS control system	Liquid level control engineering configuration based on WinCS	16
Intelligent electricity meter application capability	IM300 Communication	8
Frequency converter application capability	ACS510 Communication	6
Motor control and protection unit application capability	M102 Communication	6
Intelligent circuit breaker application capability	XT2N Communication	6
Application capability of soft starters	PSE Communication	6
Intelligent motor controller application capability	UMC100 Communication	6
Intelligent appliance comprehensive application capability	Intelligent Electrical Appliance Comprehensive Training	10

Establish a dual-track development model of "enterprise engineers leading technology application + dual-qualified teachers leading teaching transformation." At the technical level, ABB enterprise engineers will act as case technical advisors to ensure the technical accuracy of source files (e.g., WinCS configuration engineering files, XT intelligent circuit breaker control software and hardware debugging procedures, etc.). In 2024, cloud platform application cases within the Industry 4.0 framework will be introduced and integrated with subsequent graduation projects. At the teaching level, the course team will apply "cognitive load theory" [10] to deconstruct the cases for instructional purposes and develop comprehensive teaching packages comprising "knowledge maps - skill work orders - evaluation rubrics." Based on the requirements of each ability module and the relevant knowledge points and skills outlined in the curriculum standards, combined with typical real-world application scenarios of intelligent electrical technology in production and industry, the course team will collaboratively design eight teaching projects with enterprise industry engineers. These projects include intelligent controllers, intelligent ammeters, frequency converters, motor control and protection units, soft starters, intelligent motor controllers, intelligent plastic fuse circuit breakers, and overall intelligent electrical training, as shown in Table 1. All projects are derived from a water plant pump room monitoring case, and each task sets two objectives: "basic skills" and "expansion and innovation points."

2.3. The "Three-Stage Upgrade" Path of Digital Resources

Break away from the traditional resource form dominated by text and images, and construct a three-dimensional resource matrix of "static resources - dynamic simulation - integration of virtual and real worlds." At the foundational level, it includes a standardized case package comprising over 200 engineering drawings and 150 technical documents. At the enhancement level, develop simulation engineering files that integrate the majority of WinCS knowledge points, as well as 15 short videos on intelligent electrical appliances. At the innovation level, in 2025, teachers will leverage their individual teaching and research projects to introduce a cloud platform training module. This will enable students to perform remote operations and secondary development via the cloud platform, while also building interactive application practices such as "communication parameter setting - configuration design - engineer station debugging - fault troubleshooting - operator station remote control."

2.3.1. Convert the Case Study into A Simulation-Based Practical Training Program

Take "Liquid Level Control Engineering Configuration Based on WinCS" as an example. This project originated from an intelligent application case of a pumping station in a certain area. Through this engineering simulation application project, students need to be familiar with the WinCS control system, understand the working principle and functional characteristics of the system, master the basic knowledge of system hardware and network, learn the configuration operations such as creating new variables, designing static pictures, and designing flowcharts, master the monitoring operations such as viewing monitoring pictures and system diagnostic pictures, learn the general principles of fault analysis, master the basic methods of FBD programming, and learn to flexibly use the simulation controller. Figure 1 shows the flowchart screen that students need to complete in class. In order to enable students to quickly and accurately master the relevant knowledge points and skill points in the practical classroom, after communicating with enterprise technicians, the project content was reasonably decomposed and 8 training tasks with different levels of difficulty and better integration of knowledge points were designed, as shown in Table 2. In addition, different teaching documents such as PPTs, course standards, and overall teaching designs were designed according to different class hours, student sources, etc.

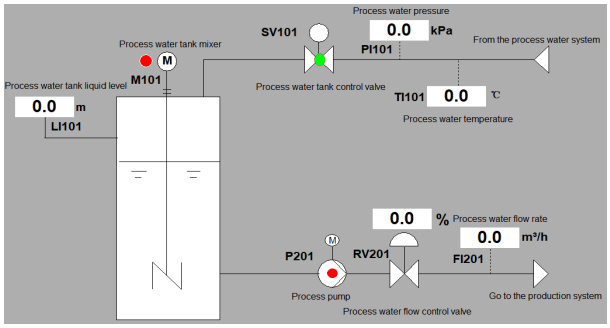


Figure 1. Simulation Screen

Table 2. Construction and Application of the Case "Liquid Level Control Engineering Configuration Based on WinCS"

Task Number	Task Content	Suggested Task Hours
1	Hardware configuration	2
2	Address mapping and range conversion	2
3	Drawing of static process flow diagrams	2
4	Implementation of dynamic flowcharts	2
5	Manual control and automatic interlock control	2
6	Realization of alarms and trends	3
7	Graphical macros and screen encapsulation	3
8	Project configuration	3

This case is designed based on the actual difficulty and the students' knowledge foundation. These tasks are completed step by step using the WinCS control system, covering main contents such as hardware configuration, screen configuration, and program configuration. At the same time, each project focuses on engineering analysis and strengthens students' cooperative awareness. It enables students to learn the WinCS control system, operate process stations and operator stations, and also enhances their ability to solve practical problems. Each of the above tasks has extracted corresponding knowledge and skill requirements. In each class, emphasis is placed on classroom discussions and the application of engineering manuals, so that students can have a clear purpose for each training session. During the training process, students can connect the knowledge points and skill points, thereby significantly enhancing the effectiveness of the training. Each project integrates the four key elements of conception, design, implementation, and operation for CDIO teaching. During the implementation process, attention is also paid to the promotion and guidance of engineering literacy and craftsmanship spirit.

2.3.2. Convert the case into an actual practical training and debugging project

The "Smart Electrical Appliances Communication Technology" course has an important task objective, which is to achieve Modbus RTU communication for typical smart electrical appliances. To achieve this goal, it is necessary to select typical smart electrical appliances and based on the WinCS control system, enable students to understand the configuration of Modbus master station blocks, network planning, resource allocation, and correct understanding of address tables. Considering the importance and practicality of intelligent molded-case circuit breakers in the field of intelligent power supply and distribution, the "XT2N Intelligent Circuit Breaker Communication" is designed as a training project, completing panel operations, parameter settings, and remote monitoring. This project requires 6 class hours to complete, and students need to achieve the design of electrical diagrams for XT circuit breaker control, the configuration of circuit breaker hardware, program configuration, and screen configuration, etc. The project begins by providing students with the XT circuit breaker application drawings that they need to understand and draw. A group consists of three students, and the drawings have three parts, each with a different focus. Each student completes the drawing design under the leadership of the group leader, while also coordinating to understand each function, demonstrating the requirements for group division of labor.

3. Teaching Transformation of Typical Cases and Implementation of CDIO

3.1. Structured Design of the Case Matrix

Based on the core technologies of intelligent appliances, a three-level case system of "basic skills - comprehensive application - innovative practice" has been established (see Table 3).

Table 3. Economic Data Statistics

Ability Level	Case Study	Technical Points	Teaching Innovation Points
Basic Skill Level	Sewage pumping station liquid level control configuration	WinCS hardware configuration, Modbus communication	Task work order + workstation members (both operator station and engineer station)
Integrated Application Layer	Remote Monitoring of Intelligent Power Distribution System	Intelligent circuit breaker communication, FBD logic control	Team collaboration + virtual debugging
Innovation Practice Layer	Intelligent equipment interconnection in the industrial internet	OPC UA protocol, edge computing gateway application	Online mentoring by enterprise experts

3.2. Deep Integration of the CDIO Model

In the comprehensive project "Intelligent Electrical Appliances Integrated Training Based on WinCS", the "conception - design - implementation - operation" four-stage teaching method is implemented. In the conception stage, real enterprise demands (such as the upgrade of the power monitoring system in a certain park) are introduced, and students form the "Technical Scheme Design Document" through research; in the design stage, electrical design is carried out using AutoCAD or EPLAN, and simulation technology is adopted to preview system operation, integrating "green manufacturing" and "safety production" as elements of course ideological education; in the implementation stage, hardware setup and program debugging are completed in the ABB intelligent power distribution joint laboratory, and the "1+X" [11] intelligent power distribution integration and operation certificate

assessment standards are introduced; in the operation stage, the system delivery is simulated through the remote operation platform, and students need to submit engineering files and training reports, with enterprise technicians participating in the evaluation.

The practice site is the hardware foundation of the CDIO teaching model. To ensure the smooth realization of teaching objectives, teachers need to build an integrated practice site that combines conception, design, practice and operation. This helps students accurately understand the project requirements. The CDIO teaching practice site needs to be equipped with projectors, resource libraries, teaching resources, etc. Students can form design plans through the query and discussion of materials in such a place. In the "Intelligent Electrical Communication Technology" course, the practice site also needs to meet the needs of students for configuration design, FBD programming, simulation experiments, and simulation design, etc. Therefore, it needs to be equipped with engineering software such as WinCS and training platforms, so that students can use different application modules according to different projects and complete different project designs. Students must conduct practical learning in such an environment, and teachers must also be proficient in using related software and hardware equipment. In the actual teaching process, the teacher selected the ABB intelligent power distribution joint application center for practical teaching. This training room has 8 sets of teaching equipment and 32 student positions. Each set of teaching equipment includes intelligent plastic-cased circuit breakers, intelligent motor controllers, frequency converters, soft starters, multi-function power meters, intelligent power monitoring systems, fast fuse protection, motor loads, etc. It can realize remote control (communication) of related intelligent devices, observe the stop, fault status display, operation status display, remote/local status of the motor under five driving methods.

Project case studies are the key elements for implementing the CDIO teaching model in this course. During the selection process, it is necessary to meet the basic requirements of the CDIO teaching model, while also considering the actual situation of vocational college students. Traditional professional course teaching usually focuses on certain specific knowledge points when selecting projects. However, among different projects, these knowledge points have low correlation, and students cannot systematically grasp the course knowledge, and their innovation abilities cannot be fully exerted. To solve such problems, teachers should pay attention to the interrelationships between projects during the project design process. In the "Intelligent Electrical Appliance Communication Technology" course, there is a relatively complex comprehensive test project called "Intelligent Appliance Overall Training Based on WinCS", which reinforces training on most key knowledge points, allowing students to understand the importance of the correlation between knowledge points, emphasizing group cooperation and on-the-spot feedback, and strengthening students' practical and hands-on abilities.

3.3. Practical Innovation of the Integration of "Position Training, Courses, Competitions, and Certificates"[12]

Integrate case teaching with skills competitions and vocational certifications deeply. The courses are aligned with job positions, and the matching degree between the case tasks and the responsibilities of the "equipment debugging" and "system maintenance" in the intelligent electrical engineer position reaches 95%. The cases are integrated into competitions, and for five consecutive years, the instructor has been responsible for developing the "Intelligent Distribution Application" school-level competition based on the case prototype. The instructor leads the professional students to participate in the new power system competition and has won awards for three consecutive years. At the same time, the cases are linked to certificates, and the case training content covers about 60% of the assessment points of the "1+X" intelligent distribution integration and operation certificate. In 2023, the pass rate of students' certificate examinations increased to over 90%.

4. Teaching Practice Outcomes and Future Prospects

4.1. Three-Dimensional Educational Outcomes

The course is taught following the "teaching model based on work processes", using various resources such as enterprise cases for auxiliary teaching. The practical training is based on theory and the theoretical part aims to facilitate practical training, integrating the two and making them mutually dependent. Thanks to the full integration of enterprise engineering cases, the course is conducted in multiple rounds based on the CDIO model, resulting in students with the following three major characteristics: 1) Solid mastery of basic knowledge; 2) Able to participate well in the development and operation of new technologies and new products; 3) Understanding the importance of technological research and development to society, with good teamwork awareness.

From the perspective of knowledge acquisition, through the comparison of pre- and post-tests, the pass rate of core knowledge for students increased from 68% to 92%, especially the application ability of complex communication protocols improved significantly. From the perspective of skill improvement, during the enterprise internship, the average time for students participating in case teaching to independently complete debugging tasks was shortened by 40%, and the satisfaction rate of enterprises for the relevant graduates exceeded 98%. From the perspective of character cultivation, the teamwork ability of students has greatly improved, and the excellent rates of "engineering standard awareness" and "innovative thinking" in the enterprise evaluations have been increasing year by year. In recent years, students of this major (pre-admission/five-year integrated program) had relatively weak theoretical foundations, but the engineering case CDIO teaching received good feedback from students, and the teaching evaluation of this course was relatively high. In the past three years, the student evaluation scores of this course have all been above 94 points.

4.2. Future Research Directions

The first thing to consider is the issue of intelligent technology empowerment. In 2026, it is planned to introduce generative AI to develop intelligent training assistants, achieving "personalized learning path recommendations + real-time fault diagnosis". At the same time, cross-regional resource sharing should also be considered. Collaborate with relevant vocational colleges to jointly build "intelligent electrical appliance case resources" and develop comprehensive training projects across enterprises and

regions. Additionally, a sustainable development evaluation should be conducted, constructing a "four-dimensional evaluation system of knowledge, skills, qualities, and social value", and introducing long-term evaluation indicators such as enterprise satisfaction and technological innovation achievements.

5. Conclusion

The "dual development of school and enterprise - three-dimensional transformation of cases - deep implementation of CDIO" model constructed in this study provides an operational methodology for the reform of higher vocational courses. In the future, it is necessary to further deepen the mechanism of industry-education integration, relying on the construction of vocational education professional teaching resource libraries and online courses, etc., to promote the digital upgrade and cross-regional sharing of case resources, and help cultivate high-quality technical and skilled talents who can meet the demands of "digital economy + green manufacturing".

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