

Teaching Reform of the Course “Programmable Industrial Control Systems” under the Engineering Education Accreditation Standards

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Abstract: Programmable logic controllers play an increasingly important role as a key component of intelligent manufacturing. The reform of corresponding courses has also become an important topic in university education. Based on a literature review and in conjunction with engineering education accreditation standards, this paper explores the teaching reform of the course “Programmable Industrial Control Systems”. It addresses aspects such as course objectives, problems to be solved, course content, teaching implementation, and assessment, with the authors’ teaching experience, and the suggestion may provide certain reference points for deeper reforms in subsequent courses.

1. Introduction

As one of the three pillars of automation in the industrial sector, PLCs (Programmable Logic Controllers) are widely used in intelligent manufacturing production lines and process industrial control systems. They are an important component of the “new infrastructure”. And the corresponding courses are also a key focus of the “new engineering” construction.

The China Engineering Education Accreditation Association introduced the “Engineering Education Accreditation Standards (2024 edition)” in November 2024[1]. Among it, the section on training objectives points out that the training objectives should reflect a general description of the professional competencies that students are expected to achieve around five years after graduation. The discipline should have clear and public training objectives. The training objectives should meet the overall requirements of educating students for the country, nurturing socialist builders and successors who are comprehensively developed in morality, intelligence, physical fitness, aesthetics, and labor. This revision better embodies the fundamental principle of “establishing virtue”, with the goal of “cultivating people”, and insists on the original intention of educating for the country.

In the training plan for the class 2024 of Electrical Engineering and Automation (Sino-German Cooperation) of Sino-German College at University of Shanghai for Science and Technology, we have clearly stated the training objectives for the program [2]. This program cultivates high-level engineering talents who are equipped to meet the needs of modern industrial development in both

China and Germany, possessing a solid foundation in German language and mathematics, as well as a systematic grasp of electrical automation technology, with an international perspective. By implementing a training model that emphasizes a strong foundation, broad scope, and practical experience, students receive basic training as electrical engineers during their studies, enabling them to engage in the design, development, and management of electrical equipment and its automation systems after graduation.

Specific goals:

(1) The students should have a solid foundation in humanities, natural sciences, and electrical engineering and its automation, as well as knowledge of cutting-edge fields;

(2) The students should have the ability to comprehensively apply knowledge of electrical engineering and its automation, to use modern engineering technology tools, and to analyze and solve complex engineering problems in the research and development, as well as project management, of electrical equipment and its automation systems, alongside practical innovation capabilities;

(3) The students should have a well-rounded character, good humanities and social sciences literacy, a correct sense of engineering ethics, and a high sense of social responsibility, adhering to the ethical standards of the engineering profession;

(4) The students should possess excellent teamwork spirit, an international perspective, and cross-cultural communication skills, along with the ability to continuously learn and adapt to developments.

The “Programmable Industrial Control Systems” course, taught by a Chinese teacher as a core subject, is open to third-year undergraduates. It has a total of 80 hours and 5 credits, with 20 hours dedicated to practical experiments. In line with the professional training objectives, the course’s aims as follows:

(1) Knowledge and skills objectives: the students can understand the basic hardware structure, functions, and application areas of PLCs; be familiar with common instruction systems and master the design methods of ladder diagrams; acquire the ability to properly install, debug, and maintain programmable control systems.

(2) Process and methods objectives: the students can develop a scientific learning perspective and methodology through the study of basic concepts, principles, instructions, and programming methods of PLCs, while cultivating the spirit and ability for autonomous learning, in-depth analysis, bold questioning, and innovation.

(3) Emotional, attitude, and value development objectives: the students can foster a rigorous scientific attitude; develop good professional ethics and emotions; enhance the ability to adapt to career changes, and nurture high-quality talents who integrate professional mission with a sense of national identity.

2. Literature Review

In recent years, the research on PLCs has mainly focused on several aspects: the introduction of teaching platforms or virtual simulations [3-6], innovation in teaching modes [7-12], and ideological and political education in courses [13].

The authors conducted relevant research on CNKI, using the search terms “Programmable Logic Controller” or “PLC” and “curriculum”. The search results are shown in Figures 1 and 2.

From Figure 1, it can be seen that since the first teaching research paper published in 1993, the annual number of publications has peaked at over 260, indicating the importance that teachers place on this course and their attempts at various teaching methods, which is commendable. This trend can be divided into four phases: from 1993 to 2006, the number increased slowly; from 2006 to

2011, the number noticeably accelerated; from 2012 to 2020, the annual publication number remained stable at over 200; from 2021 to now, the number has gradually decreased. From Figure 2, it can be seen that teaching research related to programmable logic control mainly concentrates on automation technology, vocational education, electric power industry, and higher education disciplines, accounting for 87% of the total publications.

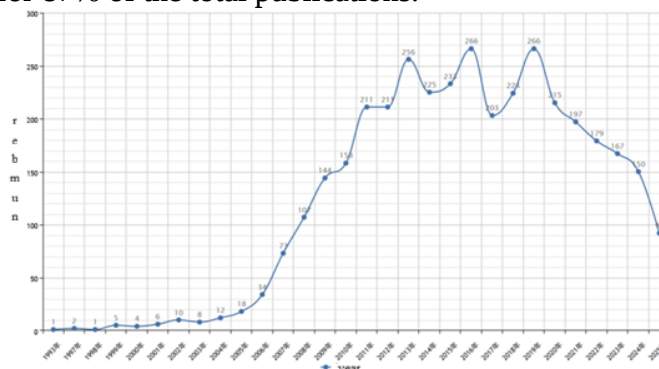


Figure 1: Annual distribution chart.

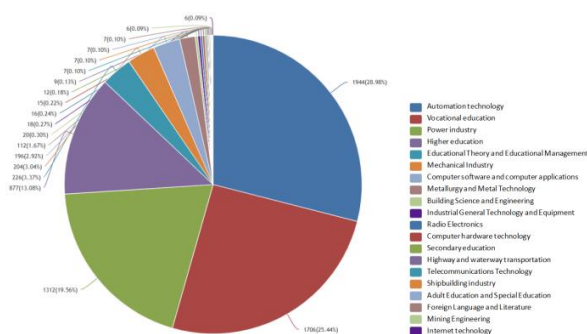


Figure 2: Subject distribution map.

3. The Key Issues in Curriculum and Teaching Reform

In the teaching process of this course, the authors have deeply considered the key issues that educational reform needs to address, specifically as follows:

(1) How can students become familiar with and truly experience the industrial environment in advance within the course? During visits to the electrical engineering laboratories of some renowned universities in China (such as Huazhong University of Science and Technology and Xiamen University), we found that this issue exists. Domestic undergraduate education has always overly focused on theoretical teaching, with not so much consideration given to aligning experimental teaching content with industrial realities. How to better integrate subject theory with industrial technology in the course, so that the training of engineering talent matches industry development, is a key concern for us.

(2) How can we increase students' participation and genuinely embody a 'student-centered' approach? Both engineering education accreditation and ASIIN accreditation advocate for a better reflection of the concept of being 'student-centered, learning outcomes-oriented, and continuously improving'. How to stimulate student enthusiasm during the teaching process, particularly in engineering education, is an issue we need to address.

(3) How can we integrate ideological and political education into the course and effectively guide students from the perspective of professional teachers? Given the active thinking characteristics of students born after 2000, coupled with their personalized and diverse needs, how

to incorporate ideological and political education into the course from the viewpoint of professional teachers to make the class lively, allowing students to enhance their moral education while mastering their professional courses, is a central topic of our research.

4. Exploration and Practice of Curriculum and Teaching Reform

4.1 Construction and application of curriculum content and resources

(1) The content increases the teaching of relay-contactor control technology considering the actual situation of the students. Relay-contactor control technology is a traditional control technology and is essential for learning and mastering PLC technology. One cannot separate PLC learning from relay-contactor control. Unlike some PLC teaching at other universities, this course integrates the practical experience of previous cohorts where the German courses did not cover relay-contactor control technology extensively, gradually intensifying the teaching of relay-contactor control technology in the curriculum.

(2) The curriculum introduces Industrial 4.0 production lines to enhance students' understanding of real industrial environments. During phase one construction of the high-level university, we have completed the application and construction process for the "Intelligent Manufacturing High-Level Laboratory" project. The laboratory has introduced the full set of Industrial 4.0 production lines from Lucas-Nuelle, making it the first to be introduced in domestic universities. The experiments in this course are based on this production line, particularly focusing on the control of 8 stations, allowing students to better experience real industrial production environments during the experiments, and exploring how it combines with the requirements of "new infrastructure" for industrial flexible production.

(3) The curriculum introduces flipped classrooms and combine them with MOOCs to enhance student engagement. Focus on addressing the problems and challenges students face during their learning through targeted explanations and analyses in class. In the learning and experimental process, encourage students to seek creative solutions to problems with specific questions and tasks, incorporating more research-based methods to better address the innovations in teaching and learning models.

(4) The curriculum is led by example and subtly guide ideological and political education in professional courses. The ideological and political education in courses should adhere to the principle of "student-centered, prioritizing moral education". Regarding the learning of PLCs in this course, we focus on the comparison between domestic and international software during routine study to enhance national confidence. We regularly set an example by ensuring students sign in on time, reasonably design online class exercises, and provide resources. While laying a solid foundation for course design and experimental exploration by meeting students' personalized and diversified needs, we encourage innovation and guide students towards inquiry-based and personalized learning.

4.2 Implementation of Course Teaching

(1) In terms of teaching methods, modern information and networking technology will be applied to teaching. The Sino-German College E-learning online teaching platform, which is an international exemplary project funded by the German DAAD, is utilized to extend classroom instruction. The total investment in the project is approximately 1.5 million euros, and the first phase of construction has passed inspection. The second phase of the project will add a Chinese interface based on the German and English versions, which has attracted more Chinese teachers to use the system. This course will leverage the online remote platform to achieve close interaction

between students and teachers, including students being able to repeatedly watch teaching videos, and submit assignments or computer programs, automatic system checks, grading of assignments or programs, and sharing of teaching materials.

(2) During the teaching process, the virtual simulation platform (see Figures 3-6) is fully utilized, and the practical examples are focused on to help students gain a deeper understanding based on principles.

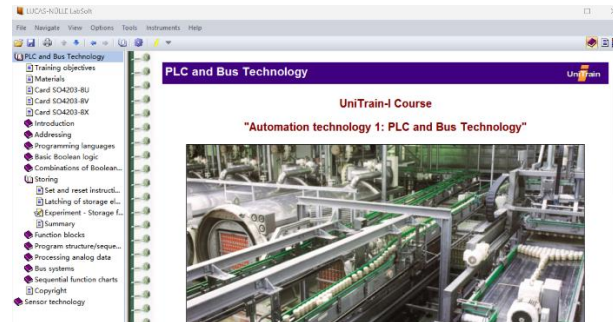


Figure 3: PLC experiment platform interface.

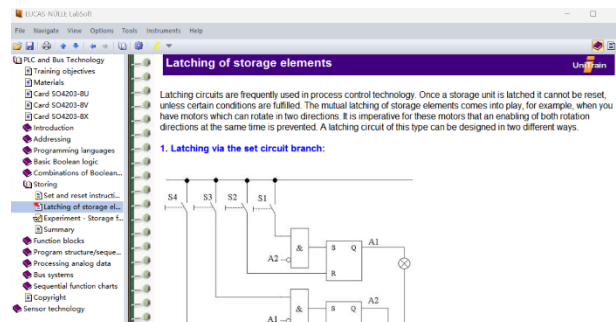


Figure 4: Knowledge point explanation interface.

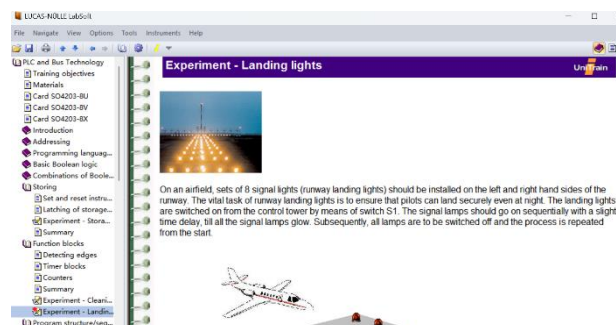


Figure 5: Experiment interface.

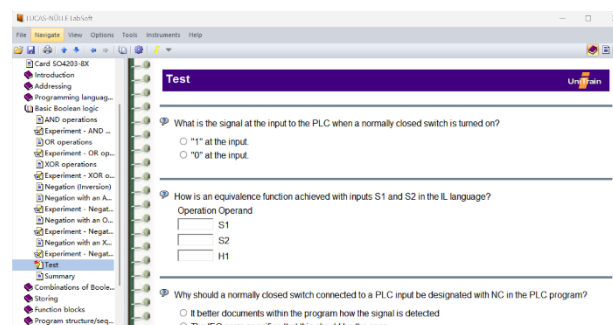


Figure 6: Testing interface.

(3) The curriculum adopts a blended teaching mode of online and offline, to enhance teaching effectiveness.

In recent years, research and practice in blended teaching have continued to deepen and emerge. Blended teaching improves learning outcomes by combining the advantages of face-to-face teaching and online learning.

The “Programmable Industrial Control Systems” course is based on several national excellent courses, allocating 20%-50% of time for online self-study, and effectively carries out a complete teaching process that closely links online and offline activities, training students’ problem-solving and critical thinking abilities. The course is also based on the E-learning online teaching platform and the university’s curriculum center online platform, employing a new integrated teaching model that is guided by video knowledge points of the course. For content that is suitable for organizing teaching in a classroom discussion format such as “Electrical Control Circuits” and “Timers”, thematic discussion classes are conducted.

(4) The integration of experimental teaching content and engineering project experiments

Based on specific industrial application projects, knowledge points are integrated into concrete engineering project experiments. When introducing project-based teaching methods, it is important to first select appropriate experimental equipment. Previously, the “Programmable Industrial Control Systems” course at the Sino-German College relied on shared experimental setups from other departments to conduct experiments. Currently, new experimental setups are being used on a project basis, allowing all students the opportunity to collaborate. A performance comparison between the new experimental setup and traditional PLC experimental setup is shown in Table 1.

Table 1: Comparison of the new PLC experimental setup with the traditional experimental setup.

	New experimental setup	Traditional experimental setup
Course content design	From the simulation perspective of actual industrial production processes, including conveyor belts and subsystems, there are stations for classification, assembly, testing, and handling, controlled by commonly used PLC systems in industry, and combined with process fieldbus and distributed peripheral devices. The course content covers learning topics such as understanding PLCs, instruction systems, and structured programming.	It is based on traditional desktop models of PLC cognition experiments.
Practical content	The practical part includes the setup of the PLC environment, the implementation of the conveyor belt functionality, the linkage of the Kuka robot, and the improvement and optimization of the product inspection system.	The practical session is mainly focused on connecting, observing signals based on desktop instruments.
Teaching characteristics	Cover “PLC Principles” and “PLC Applications”, the principles section primarily focuses on cognitive teaching, enhancing understanding of the principles based on various different instructions; the applications section is primarily centered on student projects, strengthening students’ ability to solve complex engineering problems based on specific industrial projects.	There are few relevant technology updates, and the teaching characteristics are not distinct.

4.3 Method of assessing course grades

The course adopts a comprehensive-process assessment, evaluating students’ learning attitudes, behaviors, and outcomes. The proportion of each component is shown in Table 2.

Table 2: Proportions of each component in course grade assessment.

Assessment component	Regular assessment				Final assessment	Total
Item	Attendance Q&A	Platform Assignments	On-site Experiments	Experiments Report	Final Exam	
Proportion	10%	10%	10%	10%	60%	100%

5. Conclusions

This article starts from the authors' own experiences in teaching the Sino-German professional course, explores a certain teaching reforms of "Programmable Industrial Control Systems" in conjunction with engineering education accreditation standards, and draws some beneficial conclusions. The authors will further explore deeper reforms of the course empowered by AI in the future.

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