Practical Teaching Reform and Practice of Automation Major Under the Background of "Integration of Course and Competition" - Taking the "Siemens Cup" China Intelligent Manufacturing Challenge as an Example

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Abstract. This article aims to explore the pivotal role and implementation pathways of academic competitions in cultivating the abilities of automation majors. Taking the highly representative "Siemens Cup" China Intelligent Manufacturing Challenge as a specific case, we delve into how it effectively compensates for the deficiencies of traditional classroom teaching and transforms theoretical knowledge into comprehensive engineering literacy and innovation capabilities. Through preparation and participation in competitions, students' professional hard skills, career soft skills, and forward-looking vision are cultivated.

Keywords: Competition; Automation major; Ability cultivation; Smart Manufacturing

1 Introduction

The "Siemens Cup" China Intelligent Manufacturing Challenge is a skill-based competition jointly hosted by the China Simulation Society and Siemens (China) Ltd., targeting college students nationwide. The competition covers technological innovation, product development, engineering design, and intelligent applications in the field of intelligent manufacturing. Since its first edition in 2006, the competition has been successfully held for nineteen consecutive years, with its scale continuously expanding. In 2025, 968 universities, 10,737 teams, and over 36,000 teachers and students participated. Supported by the Ministry of Education, provincial and municipal education authorities, manufacturing enterprises, and nearly 800 universities and over 2,000 colleges nationwide, the competition has become the largest and highest-level national Class A competition in the field of intelligent manufacturing in China [1].

The competition uses real engineering projects from enterprises as the contest topics, real industrial equipment and industrial environments as the competition venues, and engineering standards of relevant industrial enterprises as the assessment and scoring indicators. It comprehensively exercises students' comprehensive ability to solve

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complex engineering problems and their systematic thinking ability, providing support for cultivating and selecting technical and innovative talents capable of solving complex engineering problems for the development of intelligent manufacturing in China.

2 Competition Analysis

The "Siemens Cup" China Intelligent Manufacturing Challenge (hereinafter referred to as the "Competition") closely follows industrial development trends in its competition settings, aiming to comprehensively assess and cultivate students' innovative consciousness, comprehensive knowledge, and practical abilities in the field of intelligent manufacturing.

2.1 Competition Categories

he competition is divided into two major categories: Intelligent Manufacturing Engineering Design and Application, and Intelligent Manufacturing Innovation and Research. Each category includes multiple sub-categories. The competition in the Intelligent Manufacturing Engineering Design and Application category focuses on assessing students' abilities to propose innovative solutions for specific industrial scenarios and implement them in engineering projects, often involving the cross-integration of multidisciplinary knowledge. There are nine sub-competitions, namely Automation for Discrete Industries (Logic Algorithms), Automation for Process Industries, Automation for Discrete Industries (Engineering Practice), Motion Control for Discrete Industries, Informationization and Networking, Intelligent Equipment Design and Digital Twin Manufacturing, Lean Smart Manufacturing and Collaborative Robotics, Industrial Embedded System Development, Digital Twin Design and Development for Intelligent Production Lines, and General Direction of Intelligent Manufacturing. The Intelligent Manufacturing Innovation and Research category is further divided into competitions in the directions of Free Exploration and Industrial Hardware Research and Development [2]. The competition that is most suitable for automation majors is Automation for Process Industries, which is based on typical process industry processes such as oil refining, chemical engineering, and pharmaceuticals. It is refined from real-world engineering projects and involves knowledge such as Distributed Control Systems (DSC), industrial communication networks, human-machine interfaces, and process control engineering. Participating team members need to complete tasks such as process analysis, instrument selection, control system design, safety interlock system design, on-site wiring, control scheme implementation, exception handling, and scheme defense based on the task requirements. The knowledge that participating students need to master before the competition includes SIMATIC PCS 7 process control system, APL advanced process library, PID tuning, etc.

2.2 Competency Requirements

The Industry Automation process is the most challenging event, as it highly simulates the real-life scenarios of continuous production industries such as chemical, pharmaceutical, metallurgical, and water treatment. To achieve good results in this event, students must possess a comprehensive knowledge structure and competency system. Specific competencies are as follows:

(1)Core knowledge and technical skills

Proficient in TIA Portal software, skilled in programming complex calculations and batch control in process industries using SCL (Structured Control Language) and LAD (Ladder Diagram Language). Mastered process control principles, with a deep understanding of PID control (single-loop, cascade, feedforward, ratio, selector, etc.), and knowledge of its applicable scenarios and parameter tuning methods. Familiar with complex control system design, capable of designing control systems for complex controlled objects such as multivariable, large-lag, and nonlinear systems. Understand process control process flows, able to quickly read piping and instrumentation diagrams, comprehend process principles, equipment linkage, and safety interlock logic. Proficient in DCS/PLC system configuration, familiar with hardware configuration and network setup for process automation systems such as PCS 7 or S7-1500/ET 200SP HA. Understand the concepts and implementations of distributed I/O and redundant systems (controllers, networks, power supplies). Familiar with human-machine interface (HMI/SCADA) development, able to develop intuitive and efficient monitoring interfaces using WinCC. Understand alarm management, trend recording, user permissions, recipe management, and other functions. Familiar with the principles, selection, and signal processing of common process instruments such as temperature, pressure, flow, liquid level, and composition analysis.

(2)Systems engineering and problem-solving skills

This is the key to distinguishing between excellent and ordinary teams. The participating teams can start from scratch and design a complete automation system architecture based on the competition task specification, including the selection and layout of controllers, networks, HMI, drives, and instruments. It is not just about achieving functionality, but also about pursuing control stability, rapidity, and accuracy, that is, being able to analyze the characteristics of the controlled object, design the optimal control scheme, and proficiently perform PID parameter tuning. Various unexpected "pitfalls" may arise during the competition, and contestants need to have a clear mindset, quickly identify whether the problem lies in hardware, network, configuration, program logic, or HMI, and solve it promptly. This requires a solid theoretical foundation and rich debugging experience. The competition has a time limit, requiring the team to work together in a reasonable division of labor. At the same time, the competition task usually requires the submission of documents such as design schemes, program descriptions, and drawings, so standardized document capabilities are also an important scoring item.

(3)Personal qualities and team collaboration skills

This is the guarantee for stable performance in a high-pressure competition environment. Participating students usually work in teams of three, with clear division of labor (for example, one focuses on control strategy and programming, one focuses on HMI and networking, and one is responsible for overall design and documentation), but they also work closely together and complement each other. The pace of the competition is fast and the pressure is high, equipment may malfunction, and programs may have bugs. Staying calm and not panicking is the key to success. The competition questions may involve unfamiliar processes or new technologies, requiring rapid learning and application during preparation and competition. Automation systems have extremely high requirements for safety and stability, and even a minor error (such as a wrong address or reversed logic) can lead to the entire system failing to operate. Rigorousness and meticulousness are basic qualities of engineers.

An ideal competitor for the "Process Industry Automation" event should be a control engineer who understands the process, can comprehend and optimize the production process using automation language, can efficiently implement control concepts on the TIA Portal/PCS 7 platform, can detect and solve system problems like a detective, and can collaborate efficiently with teammates under pressure to achieve project goals. Students participating in the competition need to solidify their knowledge of textbooks such as "Process Control" and "Principles of Automatic Control", repeatedly practice TIA Portal, especially SCL and CFC programming, frequently operate, debug, and even intentionally create faults and then solve them on experimental equipment, study past competition questions, understand the question-setting ideas, difficulty levels, and common examination points, and find like-minded teammates with complementary abilities and stable emotions to form an efficient team.

3 The Relationship Between the Competition and the Automation Major

The "Siemens Cup" China Intelligent Manufacturing Challenge is one of the most important, relevant, and valuable national-level academic competitions for automation students. It has a deep complementary and mutually reinforcing relationship with the cultivation of automation students. This competition can be seen as a "comprehensive course design" or "quasi-industrial practice project" outside the automation teaching plan, and it is one of the highest stages and touchstones for practical teaching in automation. It connects the scattered knowledge points of automation (control, computer, network, programming) to build a complete knowledge system, and tests it in real industrial application scenarios.

3.1 Core Courses Accurately Correspond to Technologies

The core training objective of the automation major is to enable students to master a broad and multidimensional knowledge system encompassing control theory and systems, computer technology and applications, electrical and electronic technology, sensing and detection technology, motion control, process control, etc., and to possess the ability to solve complex engineering problems. The competition events of the "Siemens Cup" almost fully cover the aforementioned knowledge areas, and the core course knowledge of the automation major can be directly applied in the competition events. "Automatic Control Principles" is the soul of automation. In the competition, whether it is designing logic control systems, process control systems, or motion control systems, theories such as PID control, cascade control, feedforward control, etc. are required to ensure the stability, speed, and accuracy of the controlled objects (such as temperature, pressure, speed, position). PLC is the brain of industrial automation, and mainstream PLCs such as Siemens S7-1200/1500 are widely used in the competition. Students need to write programs such as ladder diagrams, SCL, GRAPH, etc., which is the ultimate practice of the "Electrical Control and PLC Application Technology" course. In the automation competition events of the process industry, process variables such as temperature, pressure, flow, and liquid level need to be controlled, which is the core content of the "Process Control System" course. The automation competition events of the process industry and discrete industry motion control require students to use software such as WinCC to design monitoring screens, achieve equipment status display, alarm processing, data recording, and other functions, which is the practical application of the "Configuration Software" course. Automation systems are not isolated islands. The competition requires proficiency in configuring and using industrial networks such as PROFIBUS, PROFINET, OPC UA, etc., to achieve data exchange between PLCs, HMI, and drive devices, which corresponds to courses such as "Industrial Communication Network". It can be seen that the competition process itself is a high-intensity, systematic, comprehensive application and practice of the core knowledge of the automation major.

3.2 The Comprehensive Training of Automation Majors' Abilities Through Competitions

This competition transcends textbooks and hones the comprehensive abilities required of automation engineers. Traditional classroom learning emphasizes theoretical instruction and fragmented experiments, whereas the competition provides a complete "project-based learning" environment that hones key skills difficult to cultivate in the classroom. In the classroom, students individually study courses such as "PLC Technology," "Sensors and Detection Technology," and "Process Control," but in the competition, team members are required to integrate this knowledge and design a complete control system from sensor signal acquisition, controller logic operations, to actuator driving and host computer monitoring. Classroom experiments are typically confirmatory, with clear steps and expected results, whereas competition problems are often open-ended, describing an industrial scenario and ultimate goal but without standard answers. Students need to define problems, design solutions, choose technical paths, debug, and optimize on their own. This process greatly cultivates innovative abilities and critical thinking. It is common for systems to fail to operate normally during competitions, encountering various unexpected failures and challenges (such as communication interruptions, control oscillations, and equipment anomalies). This requires students to have a solid theoretical foundation and strong debugging and troubleshooting abilities. Students need to use logical analysis, instrument measurements, and other methods to troubleshoot problems layer by layer, from hardware to software. This experience of solving unexpected problems under high pressure is extremely valuable and far exceeds classroom experiments. The competition is a team effort, requiring clear division of labor (such as hardware construction, software programming, and document writing), effective communication, and collaborative progress. This simulates the real project development process in enterprises and cultivates students' "soft skills." The competition forces students to use top-tier tools actually used in the industrial world, such as Siemens TIA Portal, S7-1200/1500 PLC, WinCC, and MCD. This enables them to quickly integrate into enterprises after graduation, achieving "zero-distance" employment and possessing great competitiveness in the job market.

4 Professional Talent Cultivation

Wang Juan, Li Haixia, and others have proposed a teaching reform path driven by competitions and collaborative between industry and education to address the issues existing in automation professional teaching [3]. Wang Xianju and Chen Shuguang, taking the "Siemens Cup" China Intelligent Manufacturing Challenge as an example, analyzed the role and significance of academic competitions in the cultivation of engineering talents [4]. As one of the largest and most influential student competitions in the field of intelligent manufacturing in China, the "Siemens Cup" China Intelligent Manufacturing Challenge has had a profound and multidimensional substantive impact on the training programs of automation majors in universities. It has gradually evolved from an "extracurricular competition" into an important force driving the reform of education and teaching in automation majors. In order to adapt to the rapidly developing modern industry's demand for talent capabilities, the training programs of automation majors need to be revised in a timely manner.

4.1 Setting of Training Program

The traditional automation major training program focuses on classical control theory and single-disciplinary knowledge, which is out of touch with the rapidly developing industrial world. The "Siemens Cup" China Intelligent Manufacturing Challenge serves as a "wind vane", clearly indicating that the new requirements for automation talents in modern industry have shifted from "control" to "intelligent manufacturing". This necessitates that professional training must break through the narrow perspective of "classical control" and expand into the broader ecosystem of "intelligent manufacturing". Modern engineers emphasize the concepts of "integration" and "systems". Intelligent production lines, collaborative robots, automation in discrete industries, and automation in process industries cannot be solved by a single technology. Students need to possess system integration capabilities. This has prompted the addition of courses or content related to systems engineering, digital twins, production line integration, and other related fields to the training program.

4.2 The Impact of Competitions on the Construction and Teaching Reform of Automation Major

It effectively bridges the gap between theoretical teaching and industrial practice, providing an irreplaceable platform for cultivating outstanding automation engineers who meet the requirements of "New Engineering" and the needs of future industries.

(1) Promote the reform of teaching content and methods

The technological trends and industry demands reflected in the competition will prompt teachers to update their teaching content, reduce outdated knowledge, and incorporate cutting-edge topics such as industrial networks and digital twins. Teaching methods have also shifted from "inculcation-based" to "guidance-based" and "project-based". In order to prepare for the competition, teachers and students will discover the inadequacies of existing knowledge, which will force the updating of course content and the optimization of the curriculum system. Many schools have newly introduced new courses or specialized modules such as "Industrial Data Acquisition and Monitoring (SCADA)", "Application of Digital Twin Technology", and "Industrial Information Security". Schools will pay more attention to the connection between courses, breaking down barriers between courses such as "Principles of Electric Circuits", "Electric Machinery and Drives", "Principles of Automatic Control", "PLC Technology", and "Computer Control", and designing more systematic project-based courses.

(2) Strengthen practical teaching and innovation ability cultivation

The competition exposed the shortcomings of traditional education, which emphasizes theory and belittles practice. The new training program has increased the proportion of practical teaching, significantly raising the credits and class hours allocated to practical components such as experiments, course design, and comprehensive practical training. The practice platform has been upgraded. In preparation for the competition, many universities have invested in building or upgrading simulation training platforms and procured software and hardware that are in sync with modern industrial practices (such as Siemens TIA Portal, Process Simulate, SINAMICS drives, etc.). These platforms are subsequently used in daily teaching, benefiting all students. The teaching mode has undergone some changes, promoting the model of "promoting learning and teaching through competitions". Competition projects are transformed into teaching cases, and project-based learning and case-based teaching are carried out, greatly enhancing students' ability to solve complex engineering problems.

(3) Rebuilding the faculty development

The guidance competition imposes extremely high demands on teachers, effectively promoting the construction of a "double-qualified" teaching team. In order to better guide students, instructors must continuously learn new technologies and concepts, and their own engineering practice abilities are also enhanced, which in turn nurtures classroom teaching. Many teachers have achieved a qualitative leap in their engineering practice abilities through competition training and enterprise exchanges. The process of guiding competitions is also a process of teaching reflection and research for teachers, and their scientific research achievements and engineering experience can nurture classroom teaching and improve the overall teaching quality.

(4) Deepen industry-education integration and school-enterprise cooperation

The competition serves as a prime example of industry-education integration, a collaboration between Siemens and the Ministry of Education. Its successful operational model provides a template for deepening school-enterprise cooperation in automation majors. Through the competition, schools introduce advanced technologies, training resources, and industry standards from enterprises, enabling a closer integration of training programs with enterprise needs. Many universities have taken this opportunity to collaborate with enterprises such as Siemens to establish intelligent manufacturing innovation centers and industry colleges, jointly develop training programs, develop teaching resources, and even teach together.

The Siemens Cup China Intelligent Manufacturing Challenge has had a significant impact on the training program for automation majors. It has prompted a shift in the training objectives of automation majors, from cultivating "theoretical" engineers to fostering "innovative and applied" talents capable of solving complex engineering problems. In terms of training content, it has expanded from "classical control" to "intelligent manufacturing system integration". In terms of teaching methods, it has shifted from "knowledge impartation" to "project-driven ability cultivation". Therefore, when formulating or revising the training program for automation majors, the guidance, content, and standards of the competition have become an indispensable and important reference for many universities. It effectively bridges the gap between academia and industry, enhancing the quality of talent cultivation and its adaptability to industrial needs.

4.3 Reform and Optimization of the Curriculum System

The relationship between the "Siemens Cup" China Intelligent Manufacturing Challenge and the automation major curriculum is not simply one of "in-class learning and extracurricular competitions", but rather a deep interaction and integration of "competitions guiding curriculum reform and courses supporting competition levels". The traditional courses of the automation major (such as circuits, automatic control principles, motor drive, PLC fundamentals, etc.) constitute the most fundamental knowledge system for students. The role of the competition lies in testing students' comprehensive application ability of knowledge. The competition projects are not merely assessments of knowledge from a single course, but require a team to integrate knowledge from multiple courses to solve a complex, industrial-realistic systems engineering problem. The technologies used in the competition (such as TIA Portal, SINAMICS drive, SCADA, MES system, digital twins, etc.) are often mainstream or even cutting-edge applications in the current industrial world. Students will find a gap between the classical theories learned in class and the engineering practices in industry, which provides the most direct and strongest demand signal for updating course content.In order to address the challenges posed by major competitions and systematically enhance the quality of talent cultivation, the curriculum design for automation majors needs to actively seek changes.

(1) Update and iteration of course content

"Electrical and PLC Control Technology" no longer confines itself to explaining basic instructions and logical control. It significantly expands on structured programming, large-scale project program structures (such as OB/FB/FC/DB), PROFINET industrial communication, HMI/SCADA integration, and introduces integrated engineering platforms such as TIA Portal for teaching. "Motion Control System" has shifted from primarily focusing on theory to incorporating practical aspects such as parameter setting, optimization, and collaborative control with PLCs for servo drives and frequency converters. "Process Control System" has increased the proportion of advanced control algorithms such as MPC, DCS system configuration, and Safety Instrumented Systems (SIS).

(2) Introduction of new courses or modules

Many universities have introduced brand-new courses such as "Industrial Network and Communication", "Introduction to MES/MOM Systems", "Application of Digital Twin Technology", "Industrial Data Acquisition and Monitoring (SCADA)", and "Industrial Information Security". The content of these courses is directly derived from competitions and industrial needs.

(3) Strengthening of practical teaching system

Increase comprehensive and design-oriented experiments, reduce simple verification experiments, and enhance course designs and comprehensive practical training that require knowledge from multiple courses. Build high-level practical training platforms. Many universities, relying on competition demands, have established platforms such as the "Intelligent Manufacturing Production Line Simulation Platform" and "Process Industry Simulation Platform". These platforms not only serve competition training but are also regularly used in daily teaching, benefiting all students.

(4) Transformation of teaching mode

Project-based learning involves introducing competition projects or simplified industrial cases into the classroom, allowing students to complete a complete project in groups, simulating competition and real work scenarios. "Using competition as training" and "integration of competition and curriculum": competitions are used as part of the assessment for certain practical courses, or specialized "competition elective courses" are offered, systematizing and curricularizing the preparation process.

5 Student Ability Cultivation

To participate in the "Siemens Cup" China Intelligent Manufacturing Challenge, students need to be proficient in core professional knowledge, master official tool software, and form a team with complementary strengths. Ma Xin and Li Dazi elaborated on the competition purpose and mode of the "Siemens Cup" China Intelligent Manufacturing Challenge, explaining its role in cultivating engineering innovation ability among automation major students. They pointed out that academic competitions can significantly improve college students' innovative thinking and skills, consolidate teaching achievements, and optimize the engineering innovation environment [5].

5.1 Proficient in Core Professional Knowledge

One must be proficient in programming the Siemens S7-1200/1500/300/400 series PLCs, especially with the TIA Portal software. This requires not only proficiency in ladder diagrams but also mastery of advanced languages such as SCL (Structured Control Language) and GRAPH (Sequential Function Chart). Participating students are required to perform a large number of basic exercises on simulators or physical PLCs, such as motor start-stop protection, traffic lights, conveyor belt control, etc. They should learn to use WinCC or WinCC Advanced/Professional for human-machine interface design, be able to create beautiful and practical monitoring screens, and establish variable connections with PLCs. They should understand and practice the configuration of PROFIBUS-DP and PROFINET. They should learn how to control G120 frequency converters through PLCs to achieve motor speed regulation and precise positioning. If participating in the process industry automation competition, they need to have a deep understanding of the PID control principle and be able to perform tuning and optimization.

5.2 Proficient in official Tool Software

TIA Portal (Totally Integrated Automation Portal): This is the core engineering platform for Siemens automation products, and proficiency in its use is essential. SINAMICS Startdrive: Used for configuring and commissioning frequency converters. SIZER: Used for selection and calculation of servo systems. PLCSIM: Used for software simulation of PLC programs, which is extremely useful when no hardware is available.

5.3 Build a Team with Complementary Strengths

The competition is a team event, and an ideal team should have a clear division of responsibilities, including a project leader, a hardware debugger, and a software and algorithm programmer. The project leader is responsible for schedule management, document writing, defense preparation, and coordinating internal and external relationships. The hardware debugger is responsible for hardware selection, electrical drawing design, physical wiring, network configuration, and fault troubleshooting. The software and algorithm programmer is responsible for writing the PLC core program and implementing complex control algorithms. Team members should communicate smoothly, trust each other, and may have different focuses in terms of knowledge, but they must understand each other's basic content.

6 Summary

The "Siemens Cup" China Intelligent Manufacturing Challenge is an indispensable practical teaching link in the automation professional talent cultivation system. It is not only a touchstone for testing theoretical learning outcomes, but also an incubator for stimulating students' innovative potential and cultivating their ability to solve challenges in the future intelligent manufacturing field. As Li Lijun pointed out in his research, academic skill competitions help enhance students' learning awareness, competition awareness, scientific spirit, team spirit, and organizational skills. In particular, they play an important guiding role in cultivating students' innovative abilities and are an effective way for students to grow into the excellent talents needed by enterprises. At the same time, as an extension of classroom teaching and a practical link in teaching activities, academic competitions help students master the basic abilities and skills required for practical work in their professional fields, form good professional ethics and innovative spirit, and effectively enhance their engineering practice ability and innovation and entrepreneurship literacy [6]. Huang Xiaona et al. also demonstrated through the teaching practice of the automation major at Hexi University that based on the "competition-driven teaching and learning" model, integrating competition knowledge points into experimental content, connecting competition projects with course design, and extending competition topics to graduation thesis topics can construct a closed-loop connection of "teaching-learning-practice-research", break through the bottleneck of traditional practical teaching, and effectively enhance students' innovation ability and teachers' practical teaching level [7]. Siyao Hong delved deeply into the crucial role of innovation and entrepreneurship education in fostering practical abilities among software engineering students, offering a systematic approach to enhancing their comprehensive practical skills[8].Qi Jiang and his colleagues proposed a teaching reform framework for the "Data Structures" course, aimed at addressing the limitations inherent in traditional teaching, such as the loose integration between theoretical teaching and programming practice, weak knowledge transfer ability among students, and insufficient support for formative evaluation. The goal of this framework is to cultivate students' ability to solve complex engineering problems with the assistance of artificial intelligence[9]. Consequently, universities should actively encourage and systematically organize students to participate in such competitions, deeply integrating them into talent cultivation programs. By leveraging competitions to enhance teaching, learning, and reform, the quality of automation professional talent cultivation can be effectively improved, meeting the urgent demand for high-quality engineering talents in the new engineering construction and industrial upgrading.

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