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Course Reform of Comprehensive Automation Training Focusing on Complex Engineering Problems

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Abstract

To address the insufficient ability of automation students to solve complex engineering problems and the disconnection between practical teaching and industrial reality, a systematic reform of the "Comprehensive Automation Training" course was carried out based on the engineering education accreditation philosophy of student-centered, outcome-based, and continuous improvement. The reform reconstructs project-based teaching content, designs a progressive teaching process, innovates teaching modes, establishes a diversified assessment system, and builds a university–enterprise integrated teaching platform. The full process of solving complex engineering problems is incorporated into teaching while ideological and ethical education is organically integrated. The reform achieves precise alignment between course objectives and graduation requirements, significantly improves students' engineering practice ability and comprehensive qualities, and provides a replicable paradigm for practical curriculum reform in automation programs. The results show that students' ability to analyze and solve complex engineering problems has been significantly enhanced, teamwork and engineering communication abilities have improved, and graduates' employment competitiveness has been strengthened. This study provides a reference for engineering practice curriculum reform under the background of engineering education accreditation.

Keywords

Comprehensive Automation Training; Complex Engineering Problems; Engineering Education Accreditation; Project-Based Teaching; Curriculum Reform; Practical Teaching.

1. Introduction

With the advancement of emerging engineering education and the internationalization of engineering education accreditation, cultivating the ability to solve complex engineering problems has become a core requirement for automation talent training and a key assessment indicator for engineering education accreditation. Comprehensive Automation Training is a core intensive practical course for undergraduate automation majors (4 credits, 4 weeks). It serves as an important bridge between theoretical courses and engineering practice. However, traditional teaching methods still exhibit several shortcomings, including fragmented teaching content, lack of complex engineering problem scenarios, teacher-centered teaching modes that suppress students' independent exploration, assessment systems not closely aligned with course objectives, and insufficient integration with real industrial constraints.

To address these issues, this study carries out systematic reform from five dimensions: teaching philosophy, teaching content, implementation process, assessment system, and teaching resources. The graduation requirements of engineering education accreditation are refined

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into specific course objectives, forming a trinity training model integrating knowledge transfer, ability cultivation, and value shaping. This reform aims to enhance students' ability to solve complex engineering problems and improve their engineering practice competence.

2. Reform Philosophy and Course Objective Positioning

2.1. Core Reform Philosophy

Following the definition of complex engineering problems in engineering education accreditation standards, three core principles are established:

(1)Goal-oriented principle. Graduation requirements are decomposed into measurable course objectives, ensuring alignment between course outcomes and program requirements.

(2)Project-driven principle. Real engineering projects derived from industrial practice and faculty research are introduced, enabling students to experience the full process of solving complex engineering problems.

(3)Multi-constraint principle. Non-technical constraints such as safety, economy, environmental impact, and sustainability are incorporated to cultivate comprehensive engineering literacy.

2.2. Alignment Between Course Objectives and Graduation Requirements

Combined with the graduation requirements of engineering education accreditation, the syllabus of Comprehensive Automation Training has formulated 5 course objectives, which accurately support the core indicators of the graduation requirements for the Automation major, forming a three-level support system of "Graduation Requirement – Indicator Point – Course Objective", as shown in Table 1.

Table 1 Support Relationship between Course Objectives and Professional Graduation Requirements

Graduation Requirement	Indicator Point of Graduation Requirement	Corresponding Course Objective	Support Level
Engineering Knowledge	Be able to seek multiple solutions to complex engineering problems in automation systems through literature analysis and research.	Course Objective 1: Ability to collect literature and propose solutions.	High (H)
Problem Analysis and Solution Design	Be able to understand factors affecting engineering design objectives and technical schemes of automation systems, and master basic design methods.	Course Objective 2: Ability to analyze engineering principles and conduct scheme feasibility study.	High (H)
Problem Analysis and Solution Design	Be able to consider multi-dimensional constraints and reflect innovative awareness in automation system design.	Course Objective 3: Ability to design hardware and software of systems and conduct innovative practice.	High (H)
Environment and Social Sustainable Development	Be able to evaluate the impact of automation system solutions on the environment and social sustainable development.	Course Objective 4: Ability to evaluate engineering schemes from environmental and social perspectives.	High (H)

Engineering Management and Economic Decision-Making	Be able to apply engineering management principles and economic decision-making methods in a multidisciplinary context.	Course Objective 5: Ability to conduct project management and cost accounting.	High (H)

3. Implementation Path of Course Teaching Reform

3.1. Reconstruction of Project-Based Teaching Content

To meet the requirements of complex engineering problems, the teaching content is reconstructed using real engineering cases derived from automotive automation and intelligent manufacturing. Ten representative topics are designed, including CNC control systems, industrial robot applications, AGV navigation systems, electric vehicle motor drive systems, and intelligent detection systems. Each topic includes technical specifications and multi-dimensional constraints such as cost, load capacity, efficiency, safety, and environmental impact. Students are required to complete a design report of no less than 4000 words, circuit schematics, control programs, and experimental verification results. This approach enhances both engineering design ability and technical documentation skills.

3.2. Seven-Stage Progressive Teaching Process

Combined with the 4-week course schedule, a progressive teaching process is designed in seven stages:Topic Selection → Team Formation → Project Training → Research Plan Formulation → Plan Implementation → Project Summary → Achievement Presentation and Communication.

Each stage specifies class hour allocation, teaching tasks and competency development objectives, so as to achieve step-by-step improvement in the ability to solve complex engineering problems.The specific class hours and task arrangement are shown in Table 2.

Table 2 Seven-Stage Teaching Implementation Process and Class Hour Allocation

Numble	Scheme 1	Scheme 2	Scheme 3
Topic Selection	2 class hours	Provide project background materials, review literature and industry resources; students select topics independently	Literature review ability, engineering problem identification ability
Team Formation	2 class hours	Form teams of 2–3 members; define roles such as project leader, hardware designer and software engineer; develop preliminary plans	Teamwork ability, project planning ability
Project Training	4 class hours	Conduct laboratory safety training, equipment operation training and engineering standard training; clarify requirements for environment, safety and other regulations	Engineering safety awareness, equipment operation ability, standardization awareness
Research Plan Formulation	3 days	Consult literature and industry regulations; complete requirement analysis; propose multiple design schemes and conduct feasibility studies; write preliminary design reports	Scheme design ability, feasibility analysis ability, regulation application ability

Plan Implementation	12 days	Complete hardware circuit construction, control program coding, system debugging and data collection; calculate experimental costs; solve engineering problems during debugging	Hardware and software design ability, fault diagnosis ability, engineering management and cost accounting ability
Project Summary	3 days	Analyze experimental data; evaluate the impact of schemes on environmental and social sustainable development; write complete design specifications and project summary reports	Data analysis ability, engineering evaluation ability, written expression ability
Achievement Presentation and Communication	1 day	Prepare defense PPT; deliver project reports and defenses; invite industry experts for comments; conduct inter group exchanges	Oral presentation ability, engineering problem review ability, innovative thinking

3.3. Team Collaboration and Virtual–Real Integrated Teaching Mode

Students form project teams simulating enterprise engineering groups. Roles such as project manager, hardware engineer, and software engineer are assigned. Virtual simulation tools such as MATLAB/Simulink and PLC simulation software are used for modeling and debugging before hardware implementation. This virtual–real integration improves engineering practice efficiency and reduces debugging difficulty.

3.4. Online and Offline Integrated Teaching Platform

An online teaching platform is established to provide course materials, project resources, and communication channels. Offline laboratory platforms including PLC systems, industrial robots, and vision systems are provided. Enterprise engineers participate in project guidance. This integrated platform supports design, simulation, debugging, and validation.

3.5. Diversified Outcome-Oriented Assessment System

The single outcome-based assessment is abandoned, and a ternary assessment system is established, consisting of Design Specification (35%) + Defense (35%) + Design Outcomes (30%).

All assessment indicators correspond to the five course objectives, realizing an accurate alignment of "Assessment – Course Objectives – Graduation Requirements".

A scoring method combining overall team assessment + individual contribution breakdown is adopted, taking into account both teamwork and differences in individual abilities.

Meanwhile, an evaluation method for the achievement degree of course objectives is established, forming a closed loop of "Assessment Data – Achievement Degree – Continuous Improvement".

4. Integration of Ethical and Ideological Education

Ethical and professional education is integrated throughout the teaching process. Safety regulations and intellectual property awareness are emphasized during project training. Students are encouraged to overcome technical challenges during implementation. Environmental and social impacts of engineering solutions are evaluated during project summary. National intelligent manufacturing development cases are introduced to cultivate responsibility and innovation awareness.

5. Teaching Effectiveness and Continuous Improvement

5.1. Teaching Effectiveness

The reform has been implemented since 2020. Students' abilities in analyzing and solving complex engineering problems have improved significantly. Students achieved outstanding performance in discipline competitions. Teamwork, engineering communication, and innovation abilities have been enhanced. The employment rate of graduates remained around 95%, and employer satisfaction exceeded 98%.

5.2. Existing Problems

Some challenges remain:

(1)Differences in interdisciplinary knowledge foundation among students.

(2)Insufficient depth of university–enterprise collaboration.

(3)Lack of dynamic process-based evaluation data.

5.3. Continuous Improvement Measures

To address these issues, the following measures are proposed:

(1)Optimize prerequisite curriculum and provide bridging courses.

(2)Strengthen university–enterprise cooperation and introduce real industrial projects.

(3)Improve dynamic evaluation tools for process assessment.

(4)Upgrade laboratory platforms with industrial-grade equipment.

6. Conclusion

This study presents a comprehensive reform of the Comprehensive Automation Training course focusing on complex engineering problems. Guided by engineering education accreditation concepts, the reform integrates project-based learning, progressive teaching processes, diversified assessment methods, and industry collaboration. The results demonstrate improved engineering practice ability, innovation capability, and professional literacy of students. The reform provides a replicable model for automation practice curriculum improvement and supports the cultivation of high-quality automation engineers for intelligent manufacturing.

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