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Research on the Education Model Construction of "Automatic Control Principle"

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Abstract: This paper addresses the practical needs of teaching reform for the "Automatic Control Principle" course within the context of emerging engineering education. By systematically analyzing the evolution of the course syllabus and integrating teaching practices in the Robotics Engineering major, an implementation path for course education is constructed, based on the in-depth exploration of educational elements and driven by competition projects. The research adopts a method combining case-based teaching and project-based learning, organically integrating professional knowledge such as control system stability analysis with the cultivation of comprehensive qualities like craftsmanship spirit and engineering ethics. The effectiveness is validated through practical platforms such as the "Siemens Cup" China Intelligent Manufacturing Challenge (CIMC). Practice shows that this model effectively enhances students' innovation capability and professional competence, with significant improvements in competition participation rates and award levels, achieving synergistic development of knowledge impartation and value guidance. Further analysis indicates that the key to the model's success lies in building a closed-loop, continuously improving teaching ecosystem. Course teaching reform requires continuous optimization of teaching strategies and strengthening of faculty development to provide robust support for cultivating engineering technical talents with both moral integrity and professional competence.

Keywords: Automatic Control Principle; Teaching Reform; Competition-Driven; Education Model; Emerging Engineering Education; Siemens Cup

1. Introduction

The "Automatic Control Principle" course, as a core foundational course for majors such as Robotics Engineering, Electrical Engineering, and Automation, plays an irreplaceable role in cultivating students' systems thinking, engineering practice ability, and innovation spirit. The arrival of the Industry 4.0 and smart manufacturing era has shifted the demands for engineering talents from solely technical skills to composite capabilities encompassing comprehensive literacy, professional ethics, and social responsibility. With the deepening of the fundamental task of fostering virtue through education in higher education in the new era, integrating value shaping into professional knowledge teaching has become a key pathway for organically combining professional education with the all-round development of individuals. As a young faculty member in the Robotics Engineering Department of the Faculty of Intelligent Technology at Shanghai Institute of Technology, the author, through teaching courses such as "Automatic Control Principle" and "Introduction to Robotics," deeply appreciates the importance of integrating educational elements into professional teaching. Based on the theory and practice of course education, and combining the evolution of the "Automatic Control Principle" syllabus at Shanghai Institute of Technology (April 2024 and August 2025 versions) along with the practical experience of guiding students to participate in the 2025 19th CIMC "Siemens Cup" China Intelligent Manufacturing Challenge, this paper explores the path and effectiveness of the education model construction for the "Automatic Control Principle" course.

Integrating value guidance into professional courses is not only a concrete action to implement the spirit of national college education conferences but also an important grasp for achieving "Three-wide Education" (i.e., all-round, whole-process, and all-encompassing education). The content of the "Automatic

Control Principle" course is abstract and theoretically intensive, involving extensive mathematical derivations and complex concepts such as Laplace transforms and frequency domain analysis. Traditional teaching tends to emphasize knowledge impartation while neglecting literacy cultivation. How to excavate the educational connotations within it and achieve a "moistening things silently" educational effect is the focus of current teaching reform. Domestic and foreign scholars have conducted numerous explorations on this, but problems often exist, such as superficial excavation of elements and the "two separate layers" phenomenon between educational elements and professional teaching. This paper, by analyzing the connotation of course education and combining teaching practice, proposes a student-centered, outcome-oriented construction approach, and uses competition as a driver to demonstrate the synergistic effect of quality education and professional cultivation. The structure of this paper is arranged as follows: the second part elaborates on the theoretical basis of course education and its points of convergence with the "Automatic Control Principle" course; the third part details the construction of the implementation framework and strategies for course education; the fourth part provides an empirical analysis through the specific case of the "Siemens Cup" competition; the fifth part evaluates the effectiveness, analyzes challenges, and proposes optimization paths; the final part summarizes the full text and prospects future research directions.

2. Theoretical Basis of Course Education and Points of Convergence with the "Automatic Control Principle" Course

The essence of course education is to integrate value shaping and ability cultivation into all aspects of professional teaching, achieving the organic unity of knowledge impartation, ability development, and character molding. Its theoretical foundation stems from constructivist learning theory and humanistic educational thought, emphasizing that students actively construct knowledge systems and value systems in authentic situations. The "Automatic Control Principle" course covers content such as system modeling, stability analysis, and correction design. Its theoretical system inherently contains rich philosophical ideas and scientific methodologies. For example, the feedback control principle embodies the dynamic balance and self-regulation laws of thing development. This principle is not only applicable to technical systems but also profoundly reflects basic laws in personal growth (e.g., self-improvement based on reflection) and social management (e.g., public opinion regulation). Stability analysis can be analogous to the stable operation of social systems, while system optimization reflects the spirit of striving for excellence and craftsmanship. These points of convergence provide fertile ground for mining educational elements.

From the literature review, existing research mainly unfolds from aspects such as teaching connotation mining, teaching mode innovation, and evaluation system construction. For instance, Liu et al. [1] proposed a content system based on four dimensions: ideals and beliefs, professional ethics, pursuit of excellence, and craftsmanship spirit; Zang et al. [2] explored online-offline blended teaching modes, emphasizing the construction of teaching case databases; Zhang et al. [3] designed comprehensive teaching objectives based on the OBE (Outcome-Based Education) concept. These studies provide a theoretical foundation for this paper but mostly focus on macro frameworks, lacking deep integration with specific teaching practices, especially competition-driven ones. Building on this, and combining the characteristics of the Robotics Engineering major, this paper emphasizes the cultivation of engineering ethics, innovation awareness, and sense of social responsibility.

A comparison of the two versions of the "Automatic Control Principle" syllabus shows that the construction of course education objectives is shifting from implicit permeation to explicit design. The 2024 syllabus clarified literacy goals such as "cultivating students' national consciousness and sense of national dignity," but the content was relatively generalized. The 2025 syllabus further refined the three-dimensional goals of "knowledge impartation, ability enhancement, and value shaping," and added specific requirements such as "strengthening teamwork and innovation spirit through competition practice." For example, in the section on "control system performance indicators," the new syllabus explicitly requires guiding students to discuss the engineering decision-making ethics and system optimization philosophy embodied in the "trade-off relationship among system speed, stability, and accuracy." This change reflects the deepening of course education from form to substance, providing clear guidance for teaching practice.

3. Construction Framework and Implementation Strategies for Course Education

The construction of course education needs to be guided by course objectives, restructuring teaching content and methods. Based on the syllabus, this paper constructs a framework centered on the main line of "Educational Elements - Teaching Methods - Evaluation Mechanism." This framework emphasizes the linkage and feedback among the three, forming a dynamically adjusted, continuously improving closed-loop system, whose core goal is to achieve resonance between professional knowledge education and comprehensive quality cultivation.[4-6]

3.1 Systematic and Contextualized Mining of Educational Elements

The systematic mining of educational elements is the primary step. Each chapter of the "Automatic Control Principle" course contains educational entry points. For example, in the introduction part, introducing ancient Chinese automatic control devices (such as the south-pointing chariot and seismoscope) and modern scientific and technological achievements (such as aerospace control and intelligent manufacturing) can stimulate students' cultural confidence and national pride. It is particularly worth exploring in depth to compare the history of automatic control technology development in China and abroad, guiding students to think about the relationship between technological evolution, social needs, and the scientific spirit. In the chapter on mathematical models of control systems, emphasizing the rigor and dialectical thinking in mathematical modeling guides students to understand the philosophical relationship between "phenomenon and essence." In the stability analysis part, comparing system stability to social stability cultivates students' overall perspective and sense of responsibility. Furthermore, when explaining "system correction," beyond technical means, it can be extended to "correction of personal behavior and self-improvement" and "adjustment and optimization of organizational or social policies," cultivating students' self-reflection ability and systems thinking. These elements need to be naturally integrated with professional knowledge to avoid forced grafting.

3.2 Diversified and Immersive Innovation in Teaching Methods

The innovation of teaching methods is key to the implementation of educational goals. Traditional lecture-based teaching is difficult to meet the needs of comprehensive education, requiring diversified approaches. The author promotes project-based learning and case-based teaching in instruction. For instance, when explaining system correction, the robot trajectory control case from the "Siemens Cup" competition is used to guide students in designing PID controllers, emphasizing the pursuit of precision and ethical constraints during the process. To enhance immersion, we introduced simulation platforms based on MATLAB/Simulink and physical control objects (such as inverted pendulums and smart cars), allowing students to deeply experience the significant impact of minor changes in theoretical parameters on system performance through the cycle of virtual simulation and physical debugging, thereby cultivating their rigorous scientific attitude and sense of responsibility. Simultaneously, online-offline blended teaching is adopted, utilizing the Superstar Learning platform resources to expand teaching carriers. The 2025 syllabus's new requirement of "integrating the craftsmanship spirit into experimental teaching" is met by combining hardware debugging and software simulation, allowing students to appreciate the importance of striving for excellence through practice. For example, during the debugging process, students are required to record and analyze the results of each parameter adjustment, write debugging logs, and reflect on the reasons for failure. This process itself is a tempering of qualities such as patience, meticulousness, and the pursuit of excellence.

3.3 Process-oriented and Comprehensive Reform of the Evaluation Mechanism

The reform of the evaluation mechanism is core to ensuring the effectiveness of education. Traditional assessment tends to focus on knowledge memorization. The 2025 syllabus incorporates educational elements into process evaluation, for example, increasing the proportion of comprehensive performance in group discussions, course papers, and experiment reports to 15%. The author introduces competition results as an evaluation reference; students' teamwork and innovative solutions in the "Siemens Cup" can be converted into course bonus points, achieving "promoting learning and cultivating virtue through competition." To measure educational effectiveness more comprehensively, we designed a diversified evaluation scale that not only focuses on the quality of technical solutions but also assesses communication efficiency and conflict resolution ability in teamwork, as well as considerations for issues such as engineering ethics and environmental sustainability in project reports. Furthermore, a 360-degree feedback mechanism combining student self-assessment, peer assessment, and instructor assessment was introduced. The data analysis function of the learning platform is utilized to conduct formative evaluations on the quality of students' posts in discussion forums and the time spent on case learning, thereby achieving dynamic and multi-dimensional measurement of educational effectiveness.

4. Practical Case of Course Education Driven by Competition - Taking the "Siemens Cup" as an Example

Competition is an important platform for testing the effectiveness of course education. It provides students with a near-authentic engineering practice environment, filled with uncertainty, time pressure, and teamwork requirements, making it an excellent arena for testing and sublimating knowledge, ability, and values. In 2025, the author guided students from the Robotics Engineering Department to participate in the 19th CIMC "Siemens Cup", focusing on smart production line control and robot integration applications. During the preparation process, the course's educational elements were fully embodied.

In the system design phase, students needed to establish mathematical models and design correction schemes for the multi-axis motion control problem in the smart production line. The author seized this opportunity to guide students to understand the relationship between the control requirements of "stability, accuracy, and speed" and engineering ethics. For example, while debugging a servo system, one student, in pursuit of speed, neglected stability, causing equipment oscillation. The author promptly guided the student to reflect on the philosophical significance of "balance and trade-off," citing the view from literature [7] that "system performance indicators are a dialectical unity of contradictions," helping the student establish systems thinking. Subsequently, we organized a small seminar where this student shared their lesson, and other students discussed it, analyzing the potential safety hazards and social risks of over-pursuing a single performance indicator in practical engineering like autonomous vehicle control algorithm design and chemical process control. Thus, a specific debugging failure was transformed into a profound collective learning experience in engineering ethics. This process not only strengthened professional knowledge but also cultivated a rigorous and truth-seeking scientific attitude.

In teamwork, educational elements were subtly integrated. The competition requires interdisciplinary collaboration; students need to divide tasks such as modeling, programming, and debugging. By emphasizing the application of automation technology in fields like national defense and aerospace, students' sense of mission and responsibility was stimulated. For instance, during the finals, the team faced a communication delay problem. Students, through repeated experiments and literature research, finally proposed a solution based on a filtering algorithm. During this nearly two-week crunch period, disagreements arose within the team regarding the technical approach. We guided them to learn the "Tuckman's stages of group development" model, recognizing that the "storming" stage is a normal process, and instructed them to establish a data-based decision-making mechanism and effective communication rules. Ultimately, this not only solved the technical problem but also significantly enhanced teamwork skills. This experience allowed students to deeply appreciate the "overcoming difficulties" craftsmanship spirit. After the competition, multiple students expressed that "combining personal skills with national needs is the value of an engineer."

The competition results fully demonstrate the effectiveness of the course education model. The team won one national first prize and two second prizes, and the author received the title of "National Excellent Instructor." In the winning solutions, students combined automatic control theory with educational concepts. For example, in the first-prize work "Intelligent Sorting

System Based on Adaptive Control," the concept of "green manufacturing" was integrated, reflecting the philosophy of digital transformation. In-depth analysis of this work shows that students not only considered sorting accuracy and efficiency but also specifically optimized energy consumption indicators and evaluated the material recyclability within the system's life cycle in their report, demonstrating comprehensive engineering literacy and a sense of responsibility. Post-competition reflection showed that 90% of students believed the competition enhanced their "sense of responsibility" and "confidence in innovation," and over 80% of students stated that through the competition, they gained a deeper understanding of the course's theoretical knowledge and a substantial leap in application ability, confirming the deep-level impact of the educational approach.

5. Effectiveness, Challenges, and Optimization Paths of the Course Education Model

Through two academic years of practice, the construction of the education model for the "Automatic Control Principle" course has achieved significant results. In terms of quantitative data, the rate of excellent scores (90 points and above) in the professional course increased from 7% to 21%. More importantly, qualitative feedback and improvements in comprehensive literacy are significant. The achievement of literacy goals was verified through questionnaires and interviews; for example, 85% of students can actively relate control principles to social phenomena, and the competition participation rate increased from 30% to 60%. We conducted tracking comparisons between students who participated in the competition and those who did not, finding that participating students demonstrated stronger innovation awareness and ability to solve complex engineering problems in subsequent graduation projects and research project applications. These data indicate that the course education model has achieved synergistic enhancement of "knowledge-ability-value."

However, challenges remain. Firstly, the depth of mining educational elements is insufficient, with some content being superficial and teaching cases scattered and unsystematic. Secondly, teachers' comprehensive teaching abilities are uneven. Especially for some young teachers, although they have strong research capabilities, they lack experience in integrating value guidance with their specialties in teaching design and classroom management, sometimes appearing rigid or deliberate. Additionally, the evaluation system still tends to emphasize quantitative indicators, making it difficult to fully measure educational effectiveness. Particularly for soft indicators such as the degree of value internalization and professional ethical judgment, there is a lack of scientific and effective long-term tracking evaluation tools.[8-10]

Aiming at these problems, this paper proposes the following optimization paths: First, deepen the construction of the teaching resource database. Not only collect cases but also establish standardized usage guidelines and teaching reflection templates for them, building a characteristic case collection integrated with Robotics Engineering. Second, strengthen teacher training. By organizing interdisciplinary "Course Education Workshops," inviting experts in pedagogy and ethics to prepare and refine lessons together with professional teachers, enhance the sensitivity of course design. Third, improve the evaluation system. Introduce digital tools, such as using natural language processing technology to analyze the emotional tendencies and value judgment keywords in students' course papers and reflection reports, to achieve dynamic monitoring of comprehensive educational effectiveness. In the future, the author will explore the application of technologies such as artificial intelligence and big data in course teaching in line with the requirements of emerging engineering education. For example, using digital twin technology to simulate the social impact of control systems—such as building a digital twin of an intelligent transportation system to allow students to intuitively observe how control strategies affect traffic efficiency, energy consumption, and public safety, thereby triggering deep thinking about the social effects of technology—further enhancing the interactivity and effectiveness of the teaching process.

6. Conclusion

The construction of an education model for the "Automatic Control Principle" course is a systematic project that requires full effort from goal setting, content restructuring, method innovation, to evaluation reform. Through theoretical sorting and practical cases, this paper demonstrates that an education model driven by competition and centered on students can effectively stimulate learning motivation and cultivate engineering talents with both professional literacy and family-country sentiment. The main contribution of this research lies in constructing an operable and evaluable implementation framework for course education and proving the unique value of competition projects in integrating knowledge, ability, and value cultivation through detailed cases. As a young teacher, the author deeply feels that course education is not only a teaching task but also an educational mission. In the future, we will continue to deepen the integration of "Automatic Control Principle" and quality education, contributing to the cultivation of outstanding talents in the field of robotics engineering in the new era.

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