

Research Article

Ideological-Political Modular Teaching Reform in Automatic Control Under Three-Dimensional Goals

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Abstract

In the context of the new era, integrating ideological and political education into engineering curricula has become a major trend and an important requirement of higher education reform. Principles of Automatic Control, as a core foundational course for automation and related engineering disciplines, not only imparts technical knowledge but also provides rich ideological and political connotations, including the cultivation of scientific spirit, adherence to engineering ethics, and the fostering of patriotic feelings. Based on the three-dimensional objectives of “scientific spirit-engineering ethics-patriotic feelings,” this paper constructs an innovative modular teaching framework for ideological and political education within this course. The reform approach systematically identifies the integration points between core control theory and ideological elements, decomposes ideological objectives into multiple teaching modules, and applies diversified instructional strategies such as case-based analysis, project-based learning, and inquiry-oriented discussion. Additionally, the reform extends practical sessions, embeds real engineering cases and national development scenarios, and builds a three-dimensional evaluation system focusing on value shaping, ability development, and knowledge mastery. Teaching practice and feedback results indicate that this reform effectively enhances students’ comprehensive competence, strengthens their value orientation and professional responsibility, and achieves an organic unity of knowledge transmission and value education, providing replicable experience and practical references for similar engineering courses.

Keywords

Political Education in Courses, Three-Dimensional Goals, Modular Instruction, Teaching Reform

1. Introduction

In 2020, the Guidelines for the Construction of Ideological and Political Education in Colleges and Universities issued by the Ministry of Education clearly proposed to “make various courses and ideological and political theory courses go in the same direction and form a synergistic effect”. This policy orientation marks that China's higher education has entered a new stage where “knowledge imparting and value guidance” are equally emphasized [1]. At present, there are three con-

traditions in the teaching of Principles of Automatic Control: first, the teaching content focuses on mathematical derivation and formula calculation, with insufficient exploration of the scientific spirit behind control theories [2, 3]; second, the practical links focus on the achievement of technical indicators, lacking the cultivation of engineering ethics and social responsibility [4]; third, most cases are foreign classic systems, with insufficient display of China's independent innovation

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achievements in control technology, making it difficult to stimulate students' patriotic feelings [5, 6]. The ABET certification standards in the United States list "ethical responsibility" as one of the seven essential abilities for graduates, and the EUR-ACE certification system in the European Union requires engineering education courses to include modules on "sustainable development and ethics" [7]. In contrast, ethics education in China's engineering courses is still in its infancy, especially in the field of automatic control. A mature teaching paradigm for organically integrating "control theory" and "ethical guidelines" has not yet been formed [8].

This study breaks through the predicament of "labeling" and "two separate tracks" in traditional engineering ideological and political education by constructing a three-dimensional ideological and political goal system of "scientific spirit-engineering ethics-patriotic feelings", and establishes a theoretical framework of "double helix structure of knowledge logic and value logic" for control courses [9, 10]. At the same time, it proposes a "control system ethical decision-making model", integrating ISO 14000 environmental management system and ISO 45001 occupational health and safety standards into teaching evaluation, expanding the evaluation dimension of ideological and political education in engineering courses [11]. At the talent cultivation level, the research results help cultivate high-quality control talents with "trinity": those who have the "rigorous and realistic" scientific spirit and can independently carry out control algorithm innovation; those who have "prudent and responsible" engineering ethics and consider safety, environmental protection, and fairness in system design; and those who establish "serving the country through science and technology" patriotic feelings and actively meet the major strategic needs of the country [12, 13].

In recent years, research on ideological and political education in courses in China has been further deepened in various disciplines, going through three stages: "theoretical exploration-practice promotion-system improvement". In the field of engineering, Liu Shufen explored and practiced the ideological and political construction model of courses with Fundamentals of Mechanical Manufacturing as the carrier, providing a useful reference for the ideological and political teaching reform of engineering professional courses [14]; the integration of ideological and political education in courses and "new engineering" provides a new perspective for the construction of talent training curriculum systems, exploring interdisciplinary education paths adapted to industrial needs [15]. Document [16] takes Electrical Machinery as an example, digs deep into ideological and political elements to integrate into the course, explores teaching reform from multiple aspects, and achieves remarkable results in improving students' professional literacy and ideological and political level; second, innovation in teaching methods. Lu Jun and Li Yang reflected on and practiced the ideological and political construction of Linear System Theory, exploring the integration path of ideological and political elements and professional

knowledge, providing references for the implementation of ideological and political education in engineering courses [17]; third, reform of practical links. Liu Changhao explored the practical dilemmas faced by the ideological and political construction of college physical education courses, analyzed the root causes of the problems, and proposed breakthrough paths, providing targeted ideas for the practice of ideological and political education in courses [18, 19]; Liu Yanchun and Lu Feng discussed the countermeasures of humanities and social sciences [20]. However, in control courses, a unified standard for quantifying students' engineering ethics awareness has not yet been formed [21].

Abroad, research related to ideological and political education in courses focuses on integrating ideological and political elements into professional teaching to cultivate students' literacy. American scholars [22] proposed introducing the "service learning" model into courses, allowing students to participate in community service projects to integrate knowledge and value guidance, effectively improving students' sense of social responsibility. In the field of engineering education, foreign countries attach great importance to engineering ethics education. For example, the National Academy of Engineering of the United States issued a report emphasizing the core position of engineering ethics in engineering education [23]. Some universities let students analyze and solve ethical problems in real situations through case discussions and project practices, improving their engineering ethics awareness. In terms of cultivating scientific spirit, foreign studies [24] pointed out that inquiry-based learning and scientific research practice can stimulate students' curiosity and exploration desire, enable them to master scientific methods and thinking, and develop a rigorous scientific attitude. For the overall research on ideological and political education in engineering courses, some foreign achievements discuss the integration of ideological and political education and disciplinary content from an interdisciplinary perspective, analyzing the internal logic and laws of ideological and political education [25]. However, foreign explorations in curriculum design and teaching method innovation still have certain enlightenment and reference value for carrying out ideological and political teaching reform of Principles of Automatic Control in China.

Based on the domestic and foreign research status, the ideological and political reform of Principles of Automatic Control has made some progress, but there are still three key problems: first, the goal system is fragmented, lacking systematic integration of scientific spirit, engineering ethics, and patriotic feelings; second, the teaching content is superficial, with low integration of ideological and political elements and professional knowledge; third, the evaluation method is simplified, making it difficult to comprehensively evaluate students' value literacy. This study addresses these problems by constructing a "goal-content-method-evaluation" four-in-one ideological and political education system in courses, providing a replicable and promotable reform plan for ideo-

logical and political education in engineering courses.

2. Methods

This study paper constructs an ideological and political modular teaching system for "Principles of Automatic Control" with the three-dimensional goals of "scientific spirit-engineering ethics-patriotic feelings". It explores integration points between course knowledge and ideological elements, decomposes ideological goals into various teaching modules, innovates teaching methods like case-based teaching and project-based learning, extends practical links, and improves the three-dimensional evaluation system of "value-ability-knowledge".

For scientific spirit cultivation, a "historical traceability-principle analysis-thinking migration" teaching method is adopted, combined with the development history of control theory and scientists' deeds. Engineering ethics education uses a typical case database and ethical review forms to strengthen students' sense of responsibility. Patriotic feelings are fostered through micro-courses on "the road to a powerful country in control technology" and local cases. A combination of process and summative evaluation is used to comprehensively assess students' comprehensive literacy, achieving the unity of knowledge imparting and value guidance.

3. Results

3.1. Constructing the Three-dimensional Goal System of "Scientific Spirit - Engineering Ethics - Patriotic Feelings"

(1) Implementation of Scientific Spirit Cultivation

In the classic control theory module, taking the teaching of "root locus method" as an example, a three-step teaching method of "historical traceability-principle analysis-thinking migration" is adopted. First, play a documentary clip of Evans extracting root locus laws from the geometric characteristics of the complex plane in 1948 to solve the problem of servo system design, combined with the display of replicas of his manuscripts, allowing students to intuitively feel the scientific exploration process of "from engineering problems to theoretical breakthroughs". Second, when deriving the rules for drawing root loci, guide students to imitate Evans' idea of "simplifying complex systems" to independently derive the root locus equation of second-order systems, experiencing the scientific research method of "bold assumption-rigorous verification". Third, organize a "scientific thinking seminar" to compare the methodological differences between Nyquist criterion (frequency domain) and root locus method (complex domain), summarize the evolution logic of "problem orientation-tool innovation-system improvement" in the development of control theory, and cultivate students' systematic thinking [26].

In the modern control theory part, a special topic "Qian Xuesen and Engineering Cybernetics" is designed around "state space method". By sorting out the process of Academician Qian Xuesen integrating engineering practice with mathematical theory to create the discipline of "Engineering Cybernetics" in 1954, focusing on analyzing his research paradigm of "decomposing complex systems into controllable subsystems". Students are required to model the access system of campus intelligent express cabinets with state space equations in groups, experiencing the dialectical unity of "holism and reductionism" in practice, and strengthening the scientific attitude of "theory serving practice".

(2) Scene-Based Integration of Engineering Ethics Education

A "control system ethical decision-making simulation database" is developed, including three types of typical cases: first, "Tesla autonomous driving system misjudgment accident". Through accident data replay and analysis of control algorithm flowcharts, guide students to discuss the priority of "algorithm optimization and life safety"; second, "work-related injury incidents caused by design defects in industrial robot collaboration systems". Combined with ISO/TS 15066 robot safety standards, require students to reconstruct safety control logic, strengthening the cognition that "technical specifications are the bottom line of ethics"; third, "environmental pollution incidents caused by cost reduction in a chemical plant's DCS system". Organize a tripartite debate on "cost-safety-environmental protection" to cultivate students' whole-life cycle ethical awareness [4]. An "ethical review form" is added in the course design process, requiring students to explain three contents when submitting control system plans: potential risks of system failure and emergency plans, energy consumption and environmental impact assessment, and analysis of the fairness of use among different user groups. For example, in the design of "intelligent greenhouse control system", it is necessary to evaluate the risk of crop loss caused by sensor failure, calculate the carbon emission coefficient of system operation, and consider the operational convenience for farmers [27].

(3) Immersive Experience of Patriotic Feelings Cultivation

A series of micro-courses "The Road to a Powerful Country in Control Technology" are created, divided into three stages: "foundation period (1950-1978)", "catching-up period (1979-2010)", and "leading period (2011-present)". In the "foundation period" module, play documentaries about the independent development of inertial control systems in the "Two Bombs and One Satellite" project, analyze the technical breakthroughs of Qian Xuesen's team under extremely difficult conditions, organize role-playing of "If I were an engineer at that time" to experience the spirit of "self-reliance"; in the "leading period" module, invite engineers of high-speed rail control systems to give online lectures, decrypt the independent process of "Fuxing" speed closed-loop control, compare the technical differences between China's CTCS-3 train control system and Europe's ETCS system, stimulating

students' innovation confidence.

3.2. Designing Modular Teaching Content

(1) Ideological and Political Penetration in Basic Theory Modules

In the teaching of "transfer function", a three-layer teaching method of "physical system-mathematical modeling-ideological and political mapping" is adopted. Taking the spring-damper system as an example, the first step is to demonstrate the vibration process of the mass block through experiments and record displacement data; the second step is to guide students to derive the transfer function, discuss why the spring mass and damper inertia (secondary factors) are ignored, and extract the scientific method of "abstraction and simplification"; the third step is to extend to the philosophical thinking of "grasping the main contradiction", explaining the wisdom of "strategic choice" combined with the decision-making background of "taking economic construction as the center" in China's reform and opening-up period.

The teaching of "state-space equations" introduces the case of "Three Gorges Power Station generator set control system". First, display the multi-variable coupling relationship of unit speed, voltage, excitation current, etc., explaining the limitations of traditional transfer function modeling; then establish a multi-input multi-output model with state-space equations, demonstrating the realization of decoupling control; finally, compare the technical indicators of China's independently developed excitation control system with imported systems, interspersing the analysis of the importance of "independent controllability of core technologies" when explaining the concepts of controllability and observability.

(2) Value Guidance in System Analysis Modules

The "stability analysis" unit designs "dual-case comparison" teaching. The positive case selects "Beidou navigation satellite attitude control system", analyzing its process of using Lyapunov method for stability margin design, explaining the rigorous attitude behind "redundancy design"; the negative case presents "a nuclear power plant cooling water pump control system shutdown accident caused by careless application of Routh criterion", organizing students to review the fault tree and write a Stability Design Responsibility Commitment to strengthen the awe of "no trivial matter in technology".

In the teaching of "dynamic performance indicators", a "PID parameter tuning competition" is held. Given the same controlled object (such as a temperature control system), students are required to adjust the proportional coefficient, integral time, and derivative time within a limited time to make the system overshoot $\leq 5\%$ and adjustment time $\leq 10s$. At the competition summary, guide students to reflect: the contradiction between "rapidity and stability" in index optimization is like the balance between "efficiency and quality" in life pursuit, cultivating dialectical thinking.

(3) Ability Building in System Design Modules

The "correction device design" unit implements "reverse

engineering" teaching. Provide the correction network circuit diagram and open-loop Bode diagram of a certain type of UAV flight control system, requiring students to: 1) backtrack the defects of the system before correction (such as insufficient phase margin); 2) analyze the mechanism of the correction device; 3) improve the correction scheme in groups to adapt to the plateau low-pressure environment. In the scheme defense, focus on evaluating three aspects: technical feasibility, cost control, and environmental adaptability, cultivating engineering practice ability.

The "intelligent control algorithm" module integrates the "rural revitalization" project. Organize students to design a "low-cost PID + fuzzy control" temperature and humidity system for greenhouses in remote areas, requiring: 1) using waste sensors to reduce costs; 2) the algorithm to adapt to grid voltage fluctuations; 3) considering farmers' cultural level when writing operation manuals. Through on-site research (or online docking), scheme iteration, and cost accounting, students can realize the social value of "technology for all".

3.3. Innovating Teaching Methods and Means

(1) In-Depth Application of Case Teaching Method

A "three-dimensional case database" is constructed, with each case including "knowledge dimension-ideological and political dimension-interactive design". Taking the "feedback control" case as an example: the knowledge dimension analyzes the three-level feedback structure of position loop, speed loop, and current loop of the "Tiangong space station sun-tracking system"; the ideological and political dimension tells the story of the research team's discovery of feedback delay problems in vacuum thermal tests and their 72-hour research process; the interactive design is "If you were a system designer, how to deal with sudden solar panel vibration interference", requiring students to submit written plans and explain the design basis.

The "case reversal" teaching method is adopted. When explaining "feedforward control", first present "a chemical plant raw material ratio control system product scrapping accident caused by not using feedforward compensation" to let students analyze the reasons; then reveal the improved effect after adding feedforward control to the system; finally, guide students to think about the application of "prevention-oriented" thinking in life planning, such as early exam preparation and career planning, realizing the migration from "engineering thinking" to "life wisdom".

(2) Closed-Loop Design of Project-Based Learning

The "intelligent warehouse AGV control system" project implements "full-process education". At the project initiation stage, invite logistics enterprise engineers to introduce the application status and technical bottlenecks of AGV in e-commerce logistics; during the implementation stage, divide into "path planning group", "motion control group", and "scheduling algorithm group", requiring cross-group daily progress synchronization to cultivate team collaboration; the

acceptance stage adopts "double-blind review", with enterprise experts evaluating technical indicators and ideological and political teachers assessing innovation awareness and responsibility reflected in project logs; in the result transformation stage, excellent schemes are recommended to participate in the "Internet +" innovation and entrepreneurship competition, docking with the technical needs of small and micro enterprises.

The "inverted pendulum control system" project integrates the concept of "fault-tolerant design". Students are required to intentionally introduce three types of faults (such as sensor noise, motor dead zone, and loose connecting rod) when building the system, recording the system instability process; then design fault diagnosis and fault-tolerant control algorithms, comparing the control effects before and after improvement; finally, write a reflection report Engineering Fault Tolerance and Life Pressure Resistance, analogy "system robustness" to "psychological resilience", realizing the collaborative cultivation of professional ability and psychological quality.

(3) Technology-Enabled Blended Teaching

A "virtual-real combination" experimental platform is developed, including: 1) virtual simulation module, using MATLAB/Simulink to build a "multi-motor synchronization control system", allowing students to modify parameters online to observe dynamic responses; 2) physical operation module, controlling the three-phase motor group in the laboratory, comparing the differences between simulation and measured data; 3) ideological and political extension module, linking to the engineering video of "Three Gorges Power Station unit synchronization control", analyzing the dialectical relationship of "simulation guides practice, but practice tests truth".

"AI learning situation analysis" is used to optimize ideological and political intervention. Collect students' classroom interaction data (such as the frequency of case discussion speeches), ideological and political reflection keywords in experimental reports, and ethical consideration dimensions in project schemes through the Learning Management System (LMS), and use natural language processing technology to analyze students' value orientation tendencies. For students with weak engineering ethics awareness, push micro-courses on "engineer professional guidelines"; for students with insufficient patriotic feelings, match documentary clips of "great power heavy equipment" to achieve personalized guidance.

4. Discussion

(1) The "time-domain response of typical links" experiment adds "data traceability" requirements

Students need to record: 1) original experimental data (including outliers); 2) data processing methods and basis; 3) error analysis (including instrument accuracy, environmental interference, etc.). For data tampering, "secondary experiment + integrity interview" is adopted, and an "integrity coefficient" (0.8-1.0) is set in the experiment score, linked to data authenticity.

The "control system simulation and debugging" experiment introduces "green design" indicators. Students are required to: 1) calculate energy consumption during control (such as integral of motor output power) in MATLAB simulation; 2) optimize control algorithms to reduce energy consumption by $\geq 10\%$; 3) submit Low-Carbon Control Scheme Manual. Excellent schemes will be recommended to the school's "energy conservation and emission reduction competition" to strengthen the "green engineering" concept.

(2) Social Integration of Course Design

The design of "PLC-based traffic light control system" adds the "special group care" dimension. In addition to conventional traffic light timing control, it requires: 1) adding a voice prompt module for the blind; 2) considering the emergency control logic for ambulance priority passage; 3) calculating the maximum tolerable waiting time for pedestrians (based on the survey of the elderly's walking speed). Through online interviews with the Disabled Persons' Federation and traffic police departments, the design scheme is improved to cultivate the awareness of "technology for the people". The "temperature control system design" introduces "cost-performance" game. Given a budget of 500 yuan, students need to weigh in component selection (sensor accuracy, controller brand, etc.): 1) control accuracy ($\pm 0.5^\circ\text{C}$ vs $\pm 1^\circ\text{C}$); 2) stability (whether to add filter circuits); 3) maintenance convenience. The final scheme needs to pass "tripartite review": technical feasibility (teachers), cost rationality (enterprise engineers), and social value (community representatives), cultivating comprehensive decision-making ability.

(3) Value Orientation of Discipline Competitions

Organize "red-themed control competitions", such as "A Tribute to the 100th Anniversary of the Founding of the Party - Automatic Flag-Raising Control System". Requirements: 1) the time for the national flag to rise to the top is strictly controlled at 46 seconds (corresponding to the 46 years from the founding of the Party to the founding of the People's Republic of China); 2) with wind disturbance compensation function (symbolizing "overcoming difficulties and obstacles"); 3) the system nameplate must be engraved with the words "Serve the Country with Exquisite Skills". The competition evaluation highlights the dual indicators of "technical realization" and "ideological and political relevance".

When guiding students to participate in the "China Graduate Innovation Chip Competition", a "national demand-oriented" topic guide is set: 1) localization of core controllers for industrial robots; 2) battery balancing control for new energy vehicles; 3) autonomous navigation of agricultural UAVs. Industry experts are invited to interpret the "bottleneck technology list", and the matching degree between entries and national needs is included in the guidance focus.

5. Conclusions

This study focuses on the ideological and political construction of Principles of Automatic Control, constructs a

three-dimensional goal system of "scientific spirit-engineering ethics-patriotic feelings", and explores specific paths of modular teaching content reconstruction, blended teaching method innovation, and multi-dimensional evaluation system construction. The research attempts to organically integrate control theory knowledge with ideological and political elements, excavate scientific thinking and value connotation in modules such as classic control theory and modern control theory, and promote teaching reform through case teaching and project-based learning. Preliminary exploration shows that relevant paths help enrich the educational dimension of courses and provide support for the coordinated development of students' professional abilities and value literacy. However, the research still has limitations, such as the need to improve the integration depth of ideological and political elements and knowledge points, and the long-term effect tracking data is not yet perfect. Future research will continue to optimize the teaching plan and further verify the universality and stability of the reform path.

Author Contributions

Xiaoyong Liu: Methodology, Formal analysis, Writing original draft, Writing - review & editing

Chengbin Zeng: Conceptualization, Resources

Xiaoliu Yang: Review & editing

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Conflicts of Interest

The authors declare no conflicts of interest.

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