

Exploration on Teaching Reform of AI-enabled Automatic Control Principle Course

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Abstract: Aiming at the problems of abstract knowledge structure, lack of intuitive connection between chapters, disconnection between theoretical analysis and engineering practice, and lag of learning evaluation feedback in the course of automatic control principle, this paper explores the teaching reform path of artificial intelligence (AI) empowerment based on the concept of outcome-based education. The course knowledge graph is constructed with modeling, analysis, correction and verification as the main line, and the semantic association between knowledge nodes, prerequisite dependence, error-prone concepts and engineering cases is designed. Through the large language model to assist in answering questions, learning portraits and hierarchical task recommendation, the teaching closed-loop of pre-school diagnosis, pre-class guidance, in-class inquiry, after-class practice and feedback is constructed to improve teaching; based on typical engineering projects such as motor speed regulation, the control theory derivation, MATLAB/Simulink simulation and artificial intelligence assisted analysis are combined. A multi-evaluation mechanism covering knowledge understanding, independent reasoning, simulation design, engineering interpretation and academic norms is established. The specific implementation plan of knowledge map construction, classroom activity organization, teaching effect forensics and risk management is put forward in order to provide an operable reference for the digital intelligence reform of control basic courses.

Keywords: Artificial Intelligence; Automatic Control Principle; Knowledge Graph; Project-driven; Outcome-based Education; Teaching Reform.

1. Introduction

With the development of artificial intelligence, intelligent manufacturing and new energy technologies, the tasks faced by automation engineers have gradually expanded from single system parameter setting to multi-source data perception, complex system modeling, control strategy design and operational performance verification. As a bridge connecting basic courses such as higher mathematics, circuit and signal analysis with professional courses such as motion control, process control and intelligent control, automatic control principle not only undertakes theoretical teaching tasks such as feedback thought, dynamic law and stability analysis, but also needs to help students form standardized engineering analysis thinking. The course involves Laplace transform, transfer function, time domain response, root locus, frequency characteristics and control system correction. The theory is closely related, and it is difficult to realize knowledge transfer by chapter-by-chapter teaching and exercise training alone.

The existing research provides reform experience from the perspectives of blended teaching, engineering practice, knowledge map and artificial intelligence assisted teaching. Wang et al. [1] combined modular content with online and offline mixed teaching. Zhang et al. [2] proposed to strengthen the cross-integration of knowledge, ability advancement and innovation training. Zhang et al. [3] combined the curriculum knowledge map with the goal problem and task-driven. Li et al. [4] discussed the path of knowledge graph supporting personalized learning and interactive exploration. Hu et al. [5] proposed to transform the teaching content, interactive mode and evaluation link through artificial intelligence. Wu et al. [6] demonstrated the value of the project through teaching with the step response test, parameter identification and model verification of the

electric heating temperature control system. These results show that AI tools can only be embedded with clear learning objectives, knowledge organization methods and practical tasks in order to avoid becoming a simple question and answer or job generation tool.

On the basis of the above research, this paper proposes a teaching scheme of knowledge map traction, AI hierarchical learning, engineering task connection and multi-evaluation closed-loop for undergraduate automatic control principle course. Different from adding intelligent answering tools alone, the scheme first clarifies the theory and ability that should be mastered, and then sets AI support in learning diagnosis, learning path recommendation, process error correction and formative feedback. At the same time, students' responsibilities of independent derivation, model reproduction and result interpretation are stipulated to ensure the discipline rigor and engineering ability of the course.

2. The Present Situation and Reform Goal of Course Teaching

2.1. The Main Problems in The Teaching Process

(1) The knowledge points are scattered in chapters, and the cross-method understanding is insufficient. The transfer function, system poles, time domain performance index, root locus and frequency margin are often introduced in different chapters. Students can complete the standard questions, but it is not easy to explain how the closed-loop poles affect the overshoot and stability at the same time, and why the root locus and frequency domain correction can serve the controller design together. The lack of visual conceptual connection makes it difficult to find the weakness of pre-study, and it is difficult for teachers to organize targeted remedies.

(2) There is a fault between mathematical derivation and

engineering phenomenon. Students can calculate the damping ratio and natural frequency of the second-order system, but they may not be able to identify the relevant parameters from the speed response of the real motor, the hysteresis of the temperature control object or the load disturbance. Simulation courses sometimes stay at the level of adjusting software parameters after a given transfer function, and lack the complete logic of data acquisition, modeling, design and verification. Some teaching reform studies also pointed out the lack of engineering scenarios and the fragmentation of verification experiments [7-10].

(3) The same teaching rhythm is difficult to take into account the basic differences, and the feedback cycle is too long. The differences in calculus, complex variable function, linear algebra and programming basis will enlarge the difficulty of subsequent learning. Traditional assignments and stage tests often only expose problems after the end of knowledge learning. It is not easy for teachers to correctly identify whether students are conceptual misunderstandings, calculation errors or inadequate interpretation of control meaning. It is also difficult to arrange appropriate challenges for students at different levels.

(4) The assessment focuses on the final results, and the boundary of AI use is not clear enough. If it is mainly based on the closed-book examination and program running screenshots to evaluate the ability, it is difficult for students to reflect their performance in scheme selection, parameter trade-off, debugging review and group collaboration. Generative AI can quickly give formulas and codes, but it may also produce error stability judgment, parameter hypothesis omission or fictitious reference materials. If there is a lack of verification requirements, it will weaken independent reasoning.

2.2. The Reform Goal Based on The OBE Concept

Table 1. The corresponding relationship between curriculum objectives, teaching tasks and evaluation evidence

Objective	Observable learning outcomes	Corresponding teaching tasks	Assessment evidence
Objective 1 fundamental knowledge	Explain core concepts and the relationships among methods	Graph-guided navigation, concept comparison	Closed-book quizzes, concept maps
Objective 2 system analysis	Build models and explain performance characteristics	Step response, root locus, frequency analysis	Derivation records, simulation curves
Objective 3 integrated design	Complete controller compensation and verification under given constraints	Integrated DC motor speed-control project	Design report, oral defense
Objective 4 norms and reflection	Verify AI suggestions and reflect on errors and limitations	Prompt records, cross-validation	Learning portfolio, reflection report

The reform adheres to the idea of learning results first, supported by teaching activities, and returning evaluation

evidence. As shown in Table 1, the course objectives are divided into four categories: knowledge objectives require understanding feedback, mathematical models, time-frequency domain analysis, and correction methods. The capability goal requires the ability to establish a typical object model, select analysis methods, and complete controller design. Literacy goals emphasize engineering constraints, data ethics, collaborative communication and normative expression. The learning development goals emphasize the use of digital tools for self-diagnosis, reflection and continuous learning. AI is responsible for providing verifiable learning support, students are responsible for logical argumentation, and teachers are responsible for teaching design and academic control.

3. AI-enabled Curriculum Knowledge Mapping and Resource System Construction

3.1. Construct a Knowledge Graph for Control System Analysis and Design

As shown in Fig 1, the curriculum knowledge map is based on the basic structure of knowledge entities, relationships, resources and learning evidence, rather than simply reproducing the textbook catalogue. The knowledge entity is set as six categories: mathematical basis, control concept, analysis method, design method, engineering object and experimental skill. The relationship is set to be pre-repaired, equivalent description, comparison, use, confusing, dependent on evidence, etc. Taking the closed-loop stability as an example, the pre-repair nodes include the characteristic equation and the pole distribution. The comparison nodes include Routh criterion, root locus and Nyquist criterion. The application node is associated with motor speed regulation and temperature control cases. Therefore, vertical knowledge dependence and horizontal method comparison are formed to help students explain under what conditions knowledge is applicable.

In the composition of the map, the teacher first establishes the core node list according to the syllabus and teaching materials, and then sorts out the key formulas, definitions, applicable conditions and typical error causes. AI can help extract keywords and propose candidate relationships, but each edge needs to be checked by teachers. For example, the open-loop amplitude margin cannot be directly labeled as a universal performance index of the closed-loop system. For non-minimum phase or delay systems, it is also impossible to simply apply the conclusions without preconditions. Through manual review and version management, the model can avoid generating content pollution knowledge graph.

Link three types of resources on the graph node: the first type is short video, concept comparison table and interactive animation, which cannot be understood. The second category is the difficulty classification problem, derivation steps and error diagnosis, and the solution is not accurate. The third category is physical objects, simulation models and real or public experimental data, which cannot be used. Define the mastery criteria for each node, such as being able to explain the conditions for the establishment of the criterion, complete the specified question type, and explain the results in the experiment, rather than judging the mastery based only on the number of clicks.

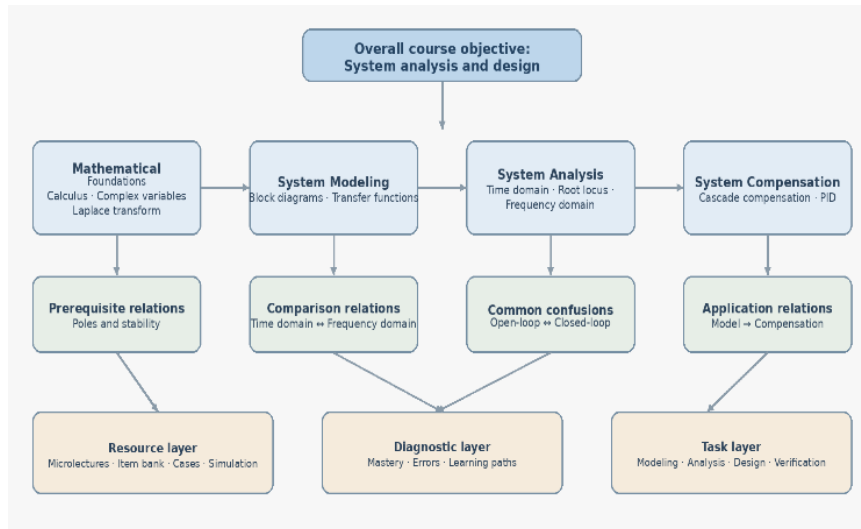


Fig 1. Knowledge Graph Structure Diagram of Automatic Control Principle Course

3.2. Using Learning Portraits to Achieve Hierarchical Navigation and Precise Assistance

The learning portrait is formed by prior knowledge diagnosis, chapter test, homework error label, simulation task completion and learning reflection. Teachers first set up a small-scale anchor question bank, and cross-examine the same knowledge point using three types of questions: concept judgment, derivation calculation and engineering interpretation. The platform then maps the results to the map nodes. If students make continuous errors in root locus drawing, the system should distinguish whether the problem comes from the interpretation of complex plane pole recognition, asymptote calculation or closed-loop pole movement, and recommend the corresponding pre-study resources and migration exercises.

The layered task adopts a three-level design of basic consolidation, comprehensive application and open expansion. The foundation layer focuses on transfer function simplification, second-order response and stability discrimination. The synthesis layer requires to compare the conclusions of different time-frequency domain methods and verify the simulation. The extended layer provides control design problems with engineering conditions such as disturbance, model uncertainty and actuator saturation. Learning recommendation is determined by graph dependence, test records and teacher-specified priorities, and teacher judgment is not replaced by a single algorithm score. Students can also view the recommended reasons and actively choose the path.

3.3. Establish a Course-specific AI Assistant and Knowledge Verification Mechanism

The course AI assistant should give priority to calling the teacher's approved lecture notes, question bank and case documents, and mark the knowledge nodes, the location of course materials and the prerequisites for solving problems when answering. For how to judge the stability of the system, how to choose PI and PID, priority should be given to follow-up questions and step-by-step prompts, rather than directly providing the final answer. The typical interaction order is: identifying known conditions, asking analysis ideas, giving

key tips, checking derivation, and asking students to explain engineering meanings. Suggestions involving safety boundaries, simulation parameters or experimental wiring must be reviewed by teachers or experimental instructors.

To prevent students from relying on AI to complete all tasks, the course adopts the three-stage requirements of independence, post-auxiliary and re-verification: students retain the first handwritten analysis or self-compiled code, indicate the AI auxiliary links and key tips, and finally cross-check with manual calculation, MATLAB/Simulink operation results or authoritative course materials to record corrections. The value of AI is not to replace the solution, but to use the limited time of students more for error location, method comparison and control decision-making.

4. AI-supported Blended Classroom and Engineering Practice Teaching Implementation

4.1. Establish a Five-loop Linkage Teaching Organization Process

As shown in Fig 2, around each knowledge unit, according to the pre-school diagnosis, pre-class guidance, in-class inquiry, after-class practice and feedback to improve the organization of teaching. Such as the second-order system performance analysis unit, the preschool push Laplace transform and the pole basic test, and the push of the map to analyze the common weak points. The pre-class configuration is about 10 minutes of micro-lessons and stratified questionnaires. In the course, prediction, discussion, derivation and simulation comparison are carried out through different damping ratio response curves. After class, the second-order model parameter identification and performance interpretation tasks are arranged. Finally, the next teaching is adjusted according to the calculation process, simulation record and reflection submitted by the students. Each step forms the corresponding learning evidence to avoid AI intervention only reflected in the use of equipment or platform.

The classroom adheres to the division of labor of teacher organization concept formation, students completing key calculations, and AI providing instant support. For the error-prone propositions such as whether increasing the

proportional gain will improve the dynamic performance, the teacher first puts forward the conflict by example, and then lets the students judge independently, and compares the overshoot, adjustment time and stability margin by simulation. AI helps to summarize the controversial points of different

groups. Finally, the teacher points out the premise of the conclusion. This process not only retains the necessary training of control theory reasoning, but also gives full play to the advantages of mathematical intelligence tools in visualization and differentiated feedback.

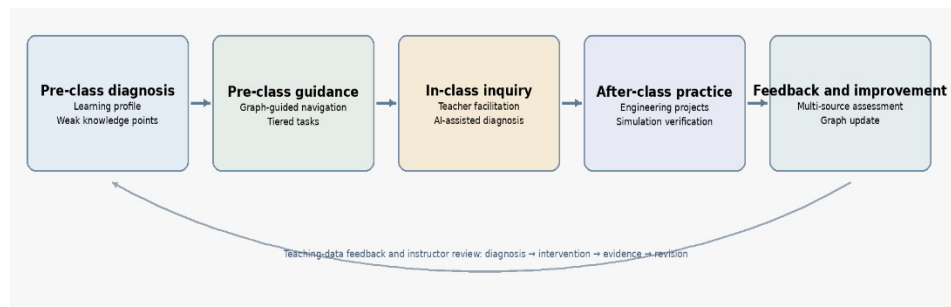


Fig 2. The Five-loop Linkage and Data Feedback Closed-loop of AI Empowerment Course Teaching

4.2. Through Modeling, Analysis and Correction of Motor Speed Regulation Task

As shown in Fig 3, DC motor speed control is selected as a penetrating project. Its physical phenomenon is intuitive, and it can connect circuit equation, mechanical motion equation, transfer function, system time domain response and feedback

correction. The project does not start from the simulation of a given transfer function, but from the engineering requirements: under the given input constraints, load changes and response time requirements, the motor speed is stably tracked to the set value. The six tasks of object cognition, data acquisition, model establishment, response analysis, PI/PID correction and disturbance verification are carried out in turn, so that the knowledge of the chapter is developed layer by layer around the same problem.

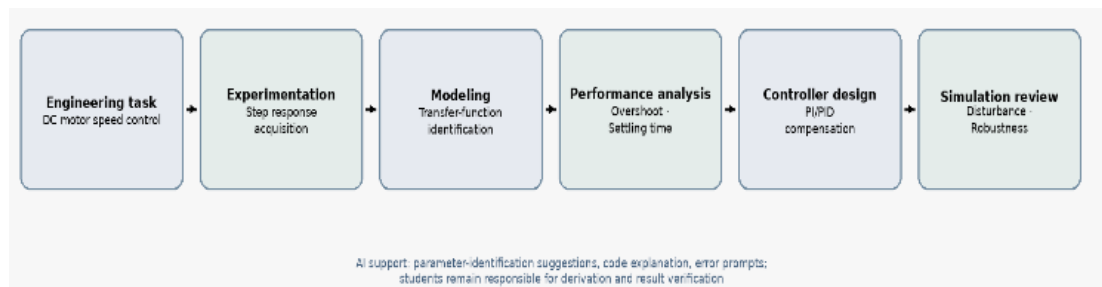


Fig 3. Task Chain and AI Auxiliary Position of Motor Speed Regulation Project

In the specific implementation, firstly, a simplified mathematical model is established based on the relationship between armature voltage, back EMF and torque, and the application scope of ignoring friction nonlinearity and parameter time-varying is discussed. Secondly, the model parameters are estimated by the step experimental data or the data provided by the teacher, and the theoretical and observed responses are compared. The steady-state error, overshoot and adjustment time are calculated again, and the influence of gain change is analyzed by means of root locus or frequency domain tool. Then the PI/PID controller is designed according to the performance requirements, and the trade-off between rapidity and overshoot is analyzed. Finally, the scheme is verified in the context of load step, model parameter deviation and actuator limitation. Students should explain the reasons for each adjustment, and not only submit screenshots of successful simulations.

In each link, AI can prompt whether the modeling dimension is consistent, assist in interpreting program errors, and generate controller tuning ideas to be tested. However, key formulas, stability judgments, and final parameter selection must be proved and reproduced by students. The different suggestions for AI require fair comparison with the same simulation conditions, so as to avoid the model replacing technical evidence with seemingly reasonable

words. For teaching classes where conditions permit, the motor project can be extended to small hardware-in-the-loop or physical experiments. Without hardware conditions, the basic tasks can also be completed with public data and reproducible simulation.

4.3. Differentiated AI Applications in Typical Knowledge Units

As shown in Table 2, in the frequency domain analysis unit, AI first helps students identify the concept distinction between open-loop frequency response and closed-loop performance, and then requires students to read the crossing frequency and phase margin under different gain conditions, and then discuss whether the index change is consistent with the time domain response. For the case of inconsistent conclusions, students are guided to check the system conditions, approximation methods and numerical settings. Such activities of hypothesis, computational analysis and evidence correction are more conducive to the cultivation of higher-order thinking than the direct generation of standard answers.

Table 2. AI Support Mode of Core Knowledge Unit and Students' Task Boundary

Teaching content	Typical difficulties	AI support mode	Tasks to be completed independently by students
Mathematical modeling	Block-diagram reduction, initial conditions	Dialog-based identification of erroneous steps	Reduction derivation and model checking
Time-domain analysis	Relationships between indices and poles	Interactive parameter animation, prompts on error causes	Index calculation and physical interpretation
Root-locus analysis	Branch trends, stability regions	Visual comparison and guided questioning	Rule derivation and result judgment
Frequency-domain analysis	Margins, phase, and stability	Curve explanation and method comparison	Bode-plot interpretation and condition verification
System compensation	Trade-off between rapidity and stability	Alternative strategies and simulation templates	Controller design and robustness verification

5. Multiple Evaluation System and Continuous Improvement of Teaching Quality

5.1. Construct a Multi-dimensional Evaluation for Learning Outcomes

Table 3. AI Support Mode of Core Knowledge Unit and Students' Task Boundary

Assessment component	Suggested weight	Key scoring criteria	Related outcomes
Graph-node quizzes	15%	Concepts, calculations, and prerequisites of applicability	Objective 1, Objective 2
In-class discussions and exercises	10%	Reasoning process, effective questioning, collaboration	Objective 1, Objective 4
Integrated engineering project	25%	Modeling, performance analysis, compensation, reproducibility	Objective 2, Objective 3
Learning portfolio and AI verification	10%	Error reflection, source verification, independence	Objective 4
Final closed-book examination	40%	Knowledge system, calculation, and analysis	Objective 1 to Objective 3

According to the curriculum objectives of Table 1, four types of evaluations are configured: knowledge test, process evidence, comprehensive design, and reflection specification, taking into account the accuracy of the results and the formation process. It is suggested that the usual learning and process evaluation accounts for 60%, and the final closed examination accounts for 40%. The former is composed of 15% node tests, 10% participation and discussion in class, 25% experimental and simulation projects, and 10% learning files and AI verification reports. This ratio is only the design of the program, the implementation should be combined with the school training program, school hours and assessment of the provisions of the adjustment. The final exam retains the

necessary theoretical analysis and calculation questions to ensure that the mathematical derivation and independent problems solving ability can be detected, as shown in Table 3.

The analytical gauge is adopted for the engineering project, and the final curve is not the only standard. It can be scored from five aspects: object model rationality, derivation and code reproducibility, performance basis of correction scheme, disturbance and uncertainty test, report and oral expression. Students' use of AI does not automatically deduct points, focusing on whether to disclose the scope of use, be able to independently retell key arguments, and be able to discover and correct AI errors. For unverified AI generation formulas or charts, even if the conclusion happens to be correct, it cannot be regarded as reliable engineering evidence.

5.2. The Effect of The Reform is Tested by Traceable Evidence

The effect of teaching reform is tested by real teaching data, and learning improvement cannot be replaced by program objectives or platform usage. It is suggested that knowledge structure test, unified engineering case task and learning experience questionnaire should be adopted before and after the implementation of the course, and the original rating scale should be retained. If the teaching conditions permit, the teaching class that implements the reform can be set up with a reference class with similar teaching progress, and the pre-test basis, post-test scores, comprehensive project scores, and achievement of each course goal can be compared. If the reference class cannot be set, the combination of the same student's pre-test and post-test, longitudinal tracking of works and teacher interview is adopted, and it is clear that the causal effect cannot be directly inferred.

The degree of achievement of curriculum objectives can be calculated according to the corresponding scores of each evaluation task: for the curriculum objective i , the sum of the actual scores of the relevant evaluation tasks is divided by the sum of the corresponding full scores, and $D_{-i} = \sum S_{-ij} / \sum M_{-ij}$ is obtained. It should be noted that whether to weight different tasks according to importance should be determined before implementation, and ensure that all classes use the same gauge. The analysis should further compare the changes of low, medium and high basic students, as well as the differences between computational and explanatory topics, so as to avoid the overall mean masking the learning difficulties of individual groups.

In the teaching operation, the error distribution and typical error causes of knowledge nodes are summarized every two to three weeks. If most students have problems in understanding the premise of Nyquist stability criterion, the interactive demonstration of open-loop pole, contour direction and closed-loop zero point is supplemented. If the robustness test in the engineering design report is generally insufficient, the parameter perturbation and disturbance control tasks are added for the next round of courses. Teachers update the map relationship, question bank and AI teaching assistant knowledge base according to the evidence, and form a continuous improvement mechanism of teaching diagnosis, intervention implementation, effect verification and resource revision.

5.3. Comparative Analysis of Student Data Before and After the Reform

To explain the evaluation method of teaching effect, a simulation sample of 60 students before and after the reform

was constructed, covering basic tests, unified tests, engineering projects, course goal attainment and questionnaire feedback. To explain the evaluation method of teaching effect, a simulation sample of 60 students before and after the reform was constructed, covering basic tests, unified tests, engineering projects, course goal attainment and questionnaire feedback. All values are simulated data of the demonstration evaluation process, not real teaching experiments or measured results. The formal submission should be replaced by the original records of the actual class. As shown in table 4, it can be seen that the mean values of the two groups of pre-tests are similar, and the scores of the unified test and the project are higher in the set sample after the reform.

Table 4. Comparison of Students' Learning Effectiveness Before and After the Reform

Evaluation indicator	Before reform	After reform
Pretest basic quiz	65.5±8.4	65.8±7.8
Final unified test	71.9±7.7	82.5±6.7
Engineering project score	74.0±7.4	85.3±4.6
Overall course grade	73.2±5.1	84.2±3.6
Pass rate (≥60)	93.3%	100.0%
High-achievement rate (≥80)	15.0%	70.0%

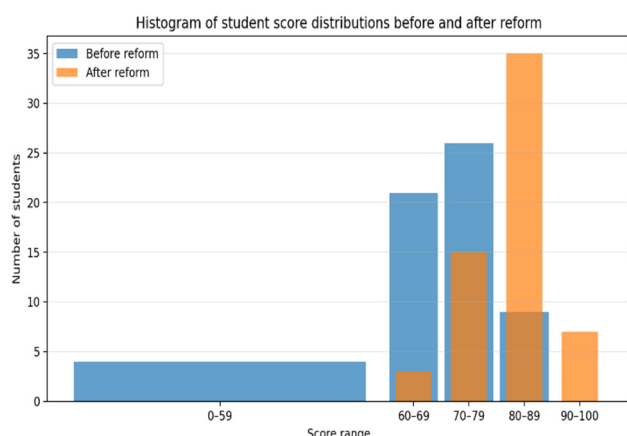


Fig 4. K Comparison Histogram of Student Achievement Distribution Before and After the Reform

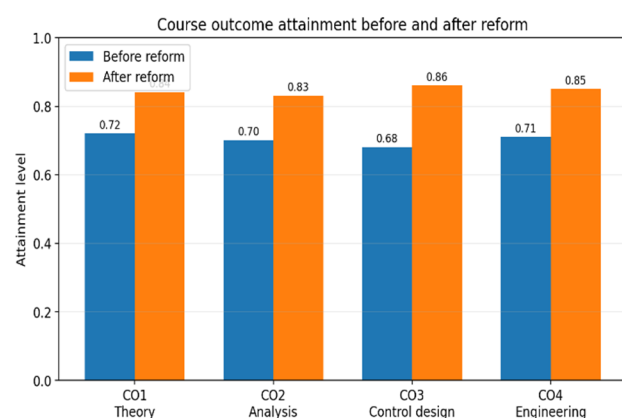


Fig 5. The Comparison of the Degree of Achievement of Curriculum Objectives Before and After the Reform

Fig 4 shows the distribution of students' scores before and after the reform. In the preset post-reform situation, the number of high-segment people increases. Fig 5 illustrates the achievement analysis method with four examples of course objectives. The results show that the setting of curriculum

objective 3 and curriculum objective 4 increases greatly. In addition, learning experience can be used as additional evidence beyond achievement. Fig 6 shows the mean value of the questionnaire of the five-level scale, which is used to measure the interest in demonstration learning, autonomous learning, perception of engineering practice, AI usage norms and satisfaction.

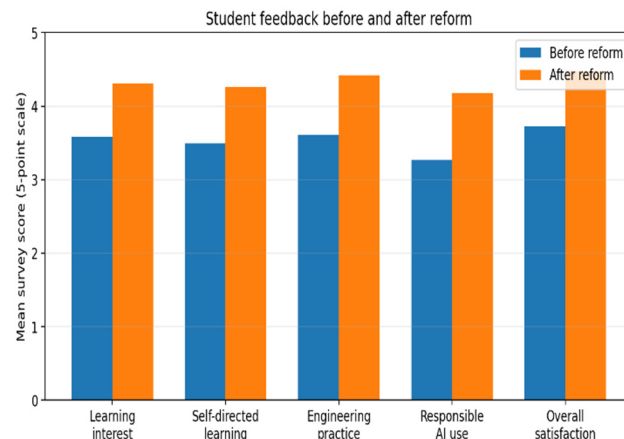


Fig 6. Comparison of Student Questionnaire Feedback Before and After the Reform

6. The Boundary, Guarantee and Promotion of AI Teaching Application

First, establish a content accuracy audit mechanism. The formulas, terms and simulation programs in the course knowledge base should indicate the source, applicable premise and revised version. Teachers review the key contents such as stability, control law and experimental safety, and students also need to provide recurrence records. Secondly, implement data protection. Learning portraits only collect the minimum information required for teaching objectives, and avoid uploading student identity information, performance details, and restricted engineering data to unauthorized external tools. Set traces, anonymization and usage instructions for AI generated content. Thirdly, pay attention to the differences between teaching fairness and digital literacy. Provide paper tasks or on-campus tools of the same difficulty to students who cannot use a certain type of AI platform stably, so as to avoid the condition of tool acquisition affecting their performance.

Teacher capacity building is also the key to the sustainable operation of the reform. Teachers need to master the skills of map node and relationship design, prompt strategy, generated content verification, course data interpretation and engineering case development, rather than only familiar with the operation of a single AI platform. The course team should divide and maintain four types of resources: concept and question bank, case and simulation, data and evaluation, and safety and ethics, and establish a semester update list to reduce fragmented and repetitive construction. In the promotion, three core units of second-order system, root trajectory and control correction can be selected first, and then the whole course can be covered after the evaluation index is stable.

Curriculum ideological and political education should also take the authenticity and responsibility consciousness of control engineering as the carrier. For example, the safety margin of industrial control system is used to discuss the

engineering personnel's judgment responsibility for risk, the technology choice in energy transformation is discussed in the context of new energy grid-connected control, and the scientific attitude of training for truth and pragmatism is verified by AI error results. Value guidance should not be used as an additional link separated from professional content, but should be reflected in practical behaviors such as parameter assumptions, engineering trade-offs, experimental records, and result disclosure.

7. Conclusion

This paper puts forward the implementation plan of promoting the reform of the course of automatic control principle by means of knowledge map, AI hierarchical assistance, engineering project and multi-evaluation. The course knowledge graph is used to establish cross-chapter connections, AI-assisted learning diagnosis and process feedback, motor speed control project penetration model establishment, performance analysis, control design and simulation verification. The simulation data show the statistical presentation of reform evaluation, but it does not constitute an empirical proof of teaching effectiveness. The next step is to test knowledge transfer, engineering design ability and learning fairness based on real teaching classes and unified gauges, and adjust teaching strategies accordingly.

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