

Teaching Reform of “Linear Systems Theory” in the Context of New Engineering Education

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Abstract: Linear system theory is an important theoretical course connecting classical control and modern control in control science and engineering, automation, electrical engineering and other majors. However, its knowledge system has the characteristics of high mathematical abstraction, strong chapter correlation and obvious dependence on engineering practice. The traditional teaching mode based on theorem derivation and exercise training is prone to problems such as calculation, difficult modeling, understanding of criteria, failure to design, ability to test, and weak practice. Facing the requirements of new engineering for solving complex engineering problems, interdisciplinary collaboration and digital practical ability, this paper constructs a curriculum teaching reform model of goal traction-content reconstruction-task driving-simulation penetration-evaluation feedback. Firstly, the course content is reorganized with the four abilities of state space modeling, system structure analysis, control synthesis and engineering innovation as the main line, and the knowledge points are embedded in engineering situations such as inverted pendulum, low-altitude aircraft attitude control and mobile robot. Secondly, MATLAB/Simulink is integrated into the whole process of theory formation, and a classroom chain of problem proposal-model establishment-theoretical analysis-numerical calculation-simulation verification-result interpretation is established. Thirdly, a multi-evaluation system combining process learning, engineering projects and final assessment is constructed. Taking the inverted pendulum as a comprehensive teaching case, the open-loop stability, controllability and observability, state feedback and state observer are numerically simulated. The simulation evaluation data of 60 students in each of the two sessions were further designed for statistical process verification. The results showed that there was no significant difference between the two pre-tests, while the total scores, engineering projects, and curriculum objectives 3 and 4 of the reform class showed more significant improvement, indicating that the reform was more conducive to the formation of comprehensive design and engineering simulation capabilities. The research provides an operable teaching framework for the transformation of control theory courses from knowledge transfer to ability generation under the background of new engineering.

Keywords: New Engineering Education; Linear System Theory; Teaching Reform; Task Driven Teaching; MATLAB/Simulink; Course Objective Attainment.

1. Introduction

With the continuous advancement of a new round of scientific and technological revolution and industrial transformation, new requirements have been put forward for the ability structure of automation and control talents in the fields of intelligent manufacturing, robots, low-altitude aircraft, new energy equipment, industrial Internet and so on [1-2]. Engineering problems are characterized by complex objects, networked systems, intelligent control and digital development tools. It is difficult to meet the needs of engineering technology development with only formula derivation and single algorithm calculation ability. The construction of new engineering emphasizes the traction of industrial demand and future technology, and strengthens the ability of interdisciplinary, engineering practice, innovative design and complex engineering problem solving, which requires the control courses to further shift from knowledge coverage to the coordinated formation of knowledge, ability and literacy.

Linear system theory is an important theoretical foundation course for control science and engineering related majors [3-4]. It mainly includes state space description, state equation solution, controllability and observability, stability theory, state feedback, pole assignment, state observer and so on. Its theoretical system is rigorous and the mathematical tools are concentrated. It not only undertakes the task of transition from classical control theory to modern control theory, but also

provides the basis for subsequent courses such as optimal control, robust control, adaptive control and model predictive control. The learning quality of the course not only affects students' understanding of the theoretical knowledge system of modern control, but also directly affects their ability to carry out scientific research modeling, algorithm design and engineering implementation.

Existing research has explored the course of linear system theory or modern control theory from the perspectives of OBE concept, task-driven, mathematical intelligence teaching, artificial intelligence integration, curriculum ideology and deep learning [5-8]. Relevant practice has proved that the introduction of engineering cases, virtual simulation and multiple evaluation can effectively improve the problem of disconnection between theory and practice in traditional classrooms. However, some reforms still remain at the local adjustment level of adding cases, adding software experiments or adding online resources. There is no stable closed loop between curriculum objectives, teaching content, classroom activities, practical tasks and evaluation evidence. Especially for the courses with strong theoretical chain such as linear system theory, if only MATLAB is put into the after-school experiment, students may still regard controllability, stability, pole assignment and observer design as isolated calculation contents.

Therefore, based on the needs of new engineering ability, this paper systematically reconstructs the linear system theory course. Reform is not to weaken the theory, but to change the

way the theory into the classroom. Explain why to learn with engineering problems, explain how to analyze with mathematical tools, answer whether the conclusion is valid with simulation experiments, and then whether the open task training can be migrated. On this basis, feedback is formed through the multi-dimensional evaluation of curriculum goal achievement and student achievement to achieve continuous improvement of the curriculum.

2. Current Teaching Practice and Needs for Reform

2.1. The theoretical Abstraction is High, and the Relationship Between Mathematical Results and Engineering Significance is Insufficient

Linear algebra, matrix theory and differential equations are widely used in the course. Traditional teaching is usually carried out according to concept-theorem-proof-example. Students can master matrix rank, eigenvalue calculation and Lyapunov equation solution, but they do not necessarily understand the engineering meaning behind the results. For example, in controllability teaching, it is easy for students to regard $\text{rank}[B, AB, \dots, A^{n-1}B] = n$ as a fixed criterion, but they do not further think about why a certain actuator position will cause some states to be unable to be driven and what will happen to the system structure after adding an input channel. When the mathematical conclusions lack the support of physical background, knowledge is easy to stay in the level of short-term memory and mechanical calculation.

2.2. Fragmented Teaching Weakens Knowledge Integration

State-space modeling, system structure analysis, stability, state feedback and state observer essentially constitute a complete engineering chain of modeling-analysis-synthesis-implementation, but textbooks are often organized independently according to chapters. After completing the controllability chapter, students often do not know why this

criterion is a precondition for subsequent pole assignment. After learning observability, it may also fail to naturally associate many states in the real system that cannot be directly measured, so state estimation must be established. This kind of chapter separation enables students to complete a single knowledge point topic, but it is difficult to face a complete object to choose the analysis and design steps independently.

2.3. Simulation Practice Lags Behind, and Tools Do Not Really Participate in Knowledge Formation.

Many courses arrange MATLAB/Simulink as an independent experimental course, and the experiment usually occurs after the theoretical teaching. Students enter `ctrb`, `obsv`, `place`, and other commands according to the instructions and get the established results. The software is only a tool to verify the answers. Under the background of new engineering, digital tools should undertake the functions of exploration, comparison and design: students should observe the response changes corresponding to different poles when learning eigenvalues, compare the convergence speed of estimation error when learning observer, and analyze the influence of pole left shift on response speed and control cost when learning state feedback. Only in this way can computing tools be truly embedded in students' cognitive process.

2.4. The Teaching Evaluation Focuses on the Final Results, and the Evidence of High-level Ability is Insufficient

The traditional course assessment is often composed of usual homework and final closed-book examination, and the questions are mainly based on concept, proof and standard calculation. This kind of assessment is suitable for evaluating the mastery of theory, but it is difficult to fully evaluate the ability of engineering modeling, software implementation, scheme comparison, result interpretation and open problem solving. If the teaching goal has shifted to solving complex engineering problems, and the evaluation still mainly examines whether it is correct, it will form an inconsistency between the goal, teaching and assessment. Therefore, it is necessary to establish observable and quantifiable evaluation evidence around the curriculum objectives.

Table 1. Main Teaching Problems and Corresponding Reform Strategies

Main problems	Traditional Practice	Reform Measures
Gap Between Theory and Engineering Practice	Formula-Oriented Teaching with Limited Physical Interpretation	Use Engineering Problems to Connect Phenomena, Models, and Theory
Fragmented Knowledge Structure	Weak Task Linkages Across Chapters	Restructure the Knowledge Chain Through Complete Control Tasks
Limited Integration of Simulation Tools	Simulation Exercises Are Mainly Used for Result Verification	Embed MATLAB/Simulink Throughout the Entire Learning Process
Limited Student Initiative	Complete solution steps are provided by the teacher	Introduce Progressive Tasks and Open-Ended Projects
Limited Diversity in Assessment Methods	Overemphasis on the Final Examination	Adopt Multiple Assessment Methods Covering Process Learning, Projects, Final Examination, and Course Objective Attainment

3. The Overall Design of Curriculum Teaching Reform Under the Background of New Engineering

3.1. Reconstructing Course Objectives Based on Competency Outcomes

The curriculum reform first solves the problem of what

ability to cultivate. Combined with the training objectives of control specialty and the requirements of new engineering, the curriculum objectives are divided into four interrelated levels. Course objective 1 is the ability of state space modeling and basic theory. It requires students to establish state space model from typical electromechanical system or dynamic process, and understand the basic relationship among state, input, output and state transition. Course objective 2 is the ability of system structure and stability

analysis, which requires students to be able to use the theory of controllability, observability and stability to explain the controllable, measurable and stable characteristics of the system. The course objective 3 is to control the comprehensive ability, which requires students to complete the state feedback, pole assignment and state observer design according to the performance requirements. Objective 4 is the ability of engineering simulation and complex problem solving. It requires students to complete the scheme implementation, parameter comparison and result interpretation with the help of MATLAB/Simulink, and to be

able to migrate the theoretical method to a certain open engineering task.

The goal of the four courses is gradually transitioning from knowledge understanding to analysis design and engineering innovation. The core of the four courses is not to simply increase the teaching content, but to enable students to form a set of transferable problem solving process after completing the course, that is, when facing the dynamic system, they can take the initiative to propose state variables, establish models, judge structural conditions, select control methods, use simulation to verify the design and explain the results.

Table 2. Alignment Among Course Objectives, Core Content, and Competency Evidence

Course Objectives	Core Content	Typical Tasks	Main Assessment Evidence
1	State-Space Modeling and State Equation Solution	State-Space Modeling of an Inverted Pendulum/DC Motor	Modeling Assignments and Interim Tests
2	Controllability, Observability, and Stability	Analysis of Actuator and Sensor Configurations	Structural Analysis Reports and Classroom Tasks
3	State Feedback, Pole Placement, and State Observers	Inverted Pendulum Stabilization and State Estimation	Comprehensive Design Project
4	Numerical Computation, Simulation, and Open-Ended Problems	Extended Cases Involving Low-Altitude Aircraft and Robots	Simulation Reports and Project Presentations

3.2. From Textbook Chapter Logic to Engineering Task Logic

On the premise of not weakening the integrity of the theoretical system, the course content is reorganized into six task modules: model representation-structural analysis stability analysis feedback synthesis state estimation comprehensive expansion. Each module is set up with a penetrating engineering object, so that students can clarify the problems that need to be solved in this module. For example, in the case of inverted pendulum, the instability phenomenon near the vertical equilibrium point is shown by open loop simulation, and the students are guided to explain the reason by using the eigenvalue of the system. Then, it is proposed whether the horizontal thrust of the car can stabilize all the states, which leads to controllability. Then, it is proposed how to realize feedback when the speed state cannot be directly measured, and naturally enter the observability and state observer. Thus, the causal relationship between knowledge is formed.

3.3. Establishing a Classroom Loop of Problem Theory Computation Simulation Interpretation

Each core knowledge point is organized in six steps : the first step is to display engineering phenomena or task requirements ; the second step is to let students put forward the theoretical problems that need to be solved ; in the third step, the teacher explains the corresponding mathematical model and theorem ; the fourth step is to complete manual derivation or key calculations by students ; the fifth step is to use MATLAB/Simulink to change the parameters and observe the results ; the sixth step requires students to explain the simulation phenomenon in engineering language. This process puts the software operation behind the theory and before the conclusion explanation, which not only avoids that the software will not theory, but also avoids that the derivation will not be applied.

3.4. Promoting Deep Learning Through Progressive Task Design

The course tasks are progressive according to the three levels of verification, design and open. Verification tasks are mainly used to understand basic concepts, such as changing the observation poles of system matrix elements and time response. The design task requires students to complete state feedback and observer parameter design according to the given performance index. The open task only gives the engineering background and performance constraints, and the students determine the model simplification, algorithm selection and simulation scheme by themselves. As the course progresses, the steps provided by the teacher are gradually reduced, so that students transition from reproducing the answer to constructing the solution path independently.

4. The Teaching Implementation of the Integration of Number Intelligence and Virtual Reality

4.1. MATLAB/Simulink Integrated Throughout Theoretical Instruction

The course no longer takes MATLAB/Simulink as a subsidiary content of a separate experimental week, but is scattered and embedded in various knowledge modules. When learning the state equation, ss and initial are used to establish the dynamic model. When learning controllability and observability, ctrb, obsv, and matrix rank are used to compare different structures. When learning stability, the intuitive relationship between pole position and system dynamics is established by eig and time domain response. When learning pole assignment, place is used to compare the adjustment time, overshoot and control input under different expected poles. When learning the observer, the real state, estimated state and error norm are drawn synchronously. In this way, a closed loop of theoretical derivation-numerical calculation-graphic observation-physical explanation is formed.

4.2. Online Resources Serve Pre-class Diagnosis and After-class Expansion

Relying on the online teaching platform, short video, knowledge map, MATLAB script template, typical error cases and hierarchical operation library are constructed. Before class, the weak points of students' prior knowledge such as linear algebra, matrix rank and eigenvalue are identified by small test. The classroom conducts intensive lectures on common problems; after class, three levels of basic questions, comprehensive questions and open tasks are provided to meet the learning needs of different students. The role of digital resources is not to increase the burden of learning, but to move low-level repeated explanations out of the classroom and use limited classroom time for reasoning, discussion and design.

4.3. Using Generative AI Appropriately to Support Student Learning

Generative artificial intelligence can be used to explain program errors, generate preliminary code frameworks, compare different control schemes, and retrieve background knowledge, but it cannot directly replace modeling and

theoretical analysis. To this end, the course project requires students to clearly write out the model assumptions, core formulas, key procedures, and independent explanations of the results in the report, and randomly ask the system behavior after the parameter changes in the defense link. The focus of the evaluation is shifted from whether there is a curve to whether it can explain why this curve is obtained, so as to prevent the alienation of tool use as the answer copy.

5. Comprehensive Teaching Case: State-space Analysis and Simulation of Inverted Pendulum System

In order to make the state space modeling, stability, controllability and observability, state feedback and state observer form a continuous knowledge chain, a typical linear inverted pendulum is selected as a comprehensive teaching case. The object has the characteristics of open-loop instability, multivariable coupling and difficulty in direct measurement of some states. It can cover the main theoretical content of the course and is easy to reproduce in MATLAB/Simulink.

Table 3. Simulation Parameters of the Inverted Pendulum

Parameters	Physical Meaning	Value
M	Cart Mass	0.5 kg
m	Pendulum Mass	0.2 kg
I	Moment of Inertia of the Pendulum	0.006 kg m ²
l	Distance to the Pendulum Center of Mass	0.3 m
b	Cart Viscous Damping	0.1 N.s/m
g	Gravitational Acceleration	9.8m/s ²

5.1. State-Space Modeling and Open-Loop Stability Analysis

The state vector $x = [x \ \dot{x} \ \theta \ \dot{\theta}]^T$ is taken, where x is the displacement of the trolley, and θ is the small deflection angle of the pendulum relative to the vertical position. The state equation can be obtained by small angle linearization near the upright equilibrium point.

$$\dot{x} = Ax + Bu \quad (1)$$

where

$$A = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & -0.1818 & 2.6727 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & -0.4545 & 31.1818 & 0 \end{bmatrix}, B = \begin{bmatrix} 0 \\ 1.8182 \\ 0 \\ 4.5455 \end{bmatrix}$$

If the cart displacement and pendulum angle are measured, the output matrix is given by $C = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}$, The eigenvalues of A are approximately $\{0, -0.1428, -5.6041, 5.5651\}$. Since one eigenvalue, 5.5651, lies in the right-half-plane, the open-loop system is unstable. In class, the open-loop response is first demonstrated through a video or real time simulation so that

students can directly observe the rapid divergence of the pendulum angle. The phenomenon is then explained using the eigenvalues, allowing the abstract statement that a right-half-plane pole causes instability to be connected with visible system behavior.

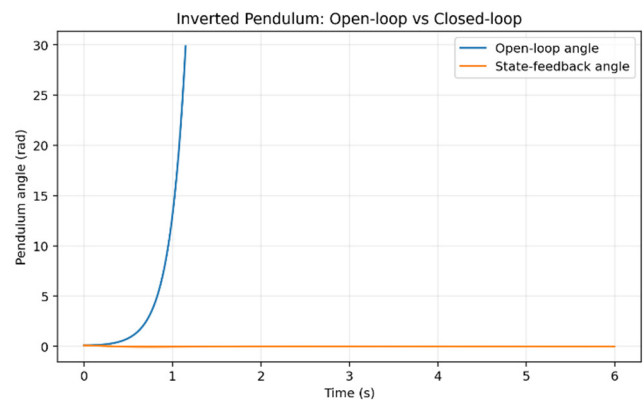


Fig 1. Open-Loop and State-Feedback Closed-Loop Pendulum Angle Responses

5.2. Controllability, Observability, and Feedback Design

The controllability matrix is constructed as $Q_c = [B \ AB \ A^2B \ A^3B]$, The calculation gives $\text{rank}(Q_c) = 4$, which is equal to the system order. This indicates that the horizontal force applied to the cart can, in

principle, influence all system states. The observability matrix is defined as

$$Q_0 = \begin{bmatrix} C^T & (CA)^T & (CA^2)^T & (CA^3)^T \end{bmatrix}^T, \quad \text{and}$$

$\text{rank}(Q_0) = 4$. Therefore, all system states can theoretically be reconstructed using measurements of only the cart position and pendulum angle. In teaching, students are further asked to modify the output matrix and compare the resulting observability after removing either the angle sensor or the position sensor. This helps to establish a direct relationship between the matrix rank and the sensor configuration.

Using the state feedback $u = -Kx$, the expected closed-loop poles are configured as $\{-2, -2.5, -3, -3.5\}$, and $K \approx [-1.1786, -1.8903, 17.1763, 3.1361]$ is obtained by using the place function. The eigenvalues of the closed-loop matrix $A - BK$ are located in the left half plane, and the system is transformed from open-loop instability to asymptotic stability. The initial swing angle $\theta(0) = 0.1 \text{ rad}$ is set, and the other states are 0. The simulation shows that the swing angle and the displacement of the car gradually converge. The teacher further enables students to shift the closed-loop poles to the left as a whole, and compare the response speed with the change of the control input peak value, so that students realize that faster is not equal to better, and there is a need to balance between control performance and control cost.

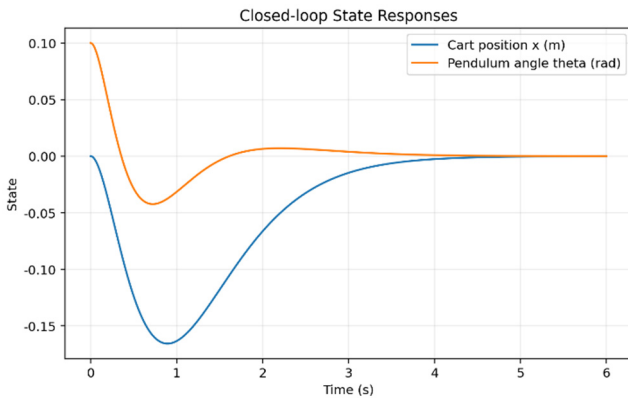


Fig 2. The Displacement and Swing Angle Response of the Car Under State Feedback

5.3. Full-Order State Observer Design and Estimation Error

The actual system usually cannot directly measure all the states, so the full-order state observer is introduced.

$$\hat{\dot{x}} = A\hat{x} + Bu + L(y - C\hat{x}) \quad (2)$$

The observer poles are set to $\{-6, -6.5, -7, -7.5\}$, and the observer gain matrix L is obtained. Since all the eigenvalues of $A - LC$ are located in the left half plane, the estimation error $e = x - \hat{x}$ is asymptotically convergent. In the simulation, the initial state of the observer is set to zero, and the feedback control is constructed by the estimated state. The error norm decays rapidly and approaches zero. This process enables students to

connect the observability criterion-observer design-estimated state feedback-separation principle into a complete chain.

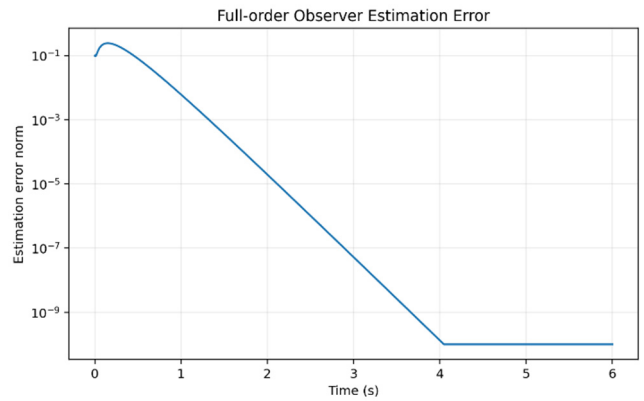


Fig 3. Estimation Error Norm of the Full-Order State Observer

The above cases are not simple software demonstrations, but are organized according to phenomenon observation-structure discrimination-controller design-observer design-performance interpretation. The final project report submitted by the students must include model assumptions, controllability and observability results, pole selection basis, control gain, observer gain, response curve and parameter change discussion. Covering multiple theoretical knowledge points through a continuous case can significantly reduce the sense of fragmentation between chapters.

6. Teaching Effect Evaluation and Simulated Data Analysis

6.1. Assessment Subjects and Grade Composition

In order to show the complete process of teaching reform evaluation, this paper constructs anonymous synthetic data according to the scale of 60 students in each of the two grades: 2024 as the traditional teaching class and 2025 as the reform teaching class. The pre-test of the two groups of students was used to test the comparability of learning basis. The total score of the course consists of 30% of process learning, 30% of engineering projects and 40% of final exams. Process learning includes classroom tasks, stage tests and after-school assignments; the main evaluation model establishment, simulation implementation, scheme design and result interpretation of the project; the final exam focuses on basic theory, calculation and comprehensive analysis. The achievement degree of curriculum objectives 1-4 is normalized from the corresponding assessment evidence to the 0-1 interval. It should be emphasized that the data in this section are used to display statistical methods and paper presentation methods, and cannot replace real teaching files.

6.2. Statistical Analysis Methods

The mean and standard deviation of the two groups of students' pre-test, total score, each assessment link and curriculum goal score were calculated respectively. Because the two classes are independent and the sample variances need not be completely equal, the Welch independent sample t -test was used to compare the differences between the groups, and $p < 0.05$ was used as the statistical significance criterion. At the same time, Cohen's d is calculated to measure the actual effect size. It is generally believed that absolute d is

about 0.2, 0.5 and 0.8, respectively, representing small, medium and large effects. Compared with only reporting how many points have been improved, giving both significance

and effect size can more objectively evaluate the actual changes brought about by the reform.

Table 4. The Composition of Course Assessment and the Support of Course Objectives

Assessment Component	Weight	Main Content	Primary Course Objectives Supported
Continuous Assessment	30%	Classroom Tasks, Stage Tests, and Assignments	Object 1, Object 2
Engineering Project	30%	Modeling, Control Design, MATLAB/Simulink Simulation, and Report Writing	Object 3, Object 4
Final Examination	40%	Fundamental Theory, Comprehensive Calculations, and Analytical Problems	Object 1, Object 2, Object 3

Table 5. Comparison of Major Indicators for the Two Cohorts

Indicator	2024 Cohort (Traditional Teaching)	2025 Cohort (Reform-Oriented Teaching)	<i>P</i> Value	Cohen's <i>d</i>
Pre-Test Scores	73.03±7.51	70.94±9.13	0.173	-0.250
Final Course Grade	75.82±7.92	80.50±8.76	0.003	0.559
Continuous Assessment	77.05±8.08	81.45±8.88	0.005	0.519
Engineering Project	74.23±8.45	82.29±8.81	<0.001	0.934
Final Examination	76.10±8.85	78.43±9.84	0.176	0.248
Object 1	76.10±8.24	80.30±8.78	0.008	0.493
Object 2	75.65±8.42	79.55±9.07	0.016	0.445
Object 3	75.34±8.08	80.91±8.80	<0.001	0.660
Object 4	75.46±8.57	81.52±8.59	<0.001	0.706

6.3. Total Score Distribution and Project Performance

The mean values of the pre-test of the two students were 73.03 and 70.94, respectively, and the Welch test ($p=0.173$), which did not reach a significant level, indicating that the basic differences between the two groups under the simulation data setting were not enough to explain the follow-up results. After the end of the course, the total score of the reform class increased from 75.82 to 80.50, and the difference reached a significant level ($p=0.003$). Cohen's $d = 0.559$, which belongs to the medium effect. The pass rate of the reform class was 100 %, and that of the traditional class was 96.7 %. The proportion of 80 points and above increased from 31.7 % to 51.7 %, and the proportion of 85 points and above increased from 8.3 % to 36.7 %. The score distribution map and box plot show that the overall position of the reform class moves to the high score interval, while still retaining certain individual differences, which is not a simple unnatural distribution with overall elevation and disappearance of variance.

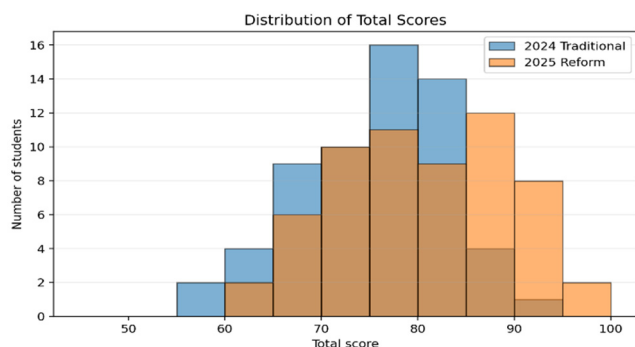


Fig 4. Overall Course Grade Distributions of the Two Cohorts

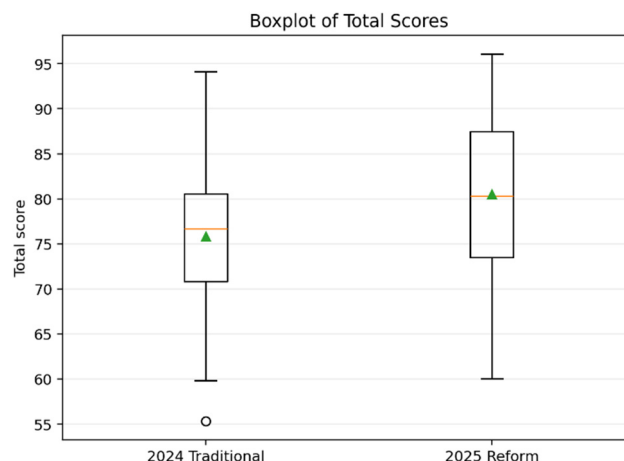


Fig 5. Box Plot of Overall Course Grades for the Two Cohorts

From the perspective of different assessment links, the improvement of the project is the most obvious: the average score of the reform class is 82.29 points, the control class is 74.23 points, $p<0.001$, Cohen's $d=0.934$, reaching a large effect; process learning also showed a moderate effect ($d=0.519$). By contrast, the final exam was only increased from 76.10 to 78.43, and the difference was not significant ($p=0.176$). This result has a strong explanatory significance of teaching reform: the reform is not achieved by reducing the difficulty of theory or simply improving the test scores, but mainly reflected in continuous learning, system design and engineering practice ability, which is in line with the reform goal of this paper.

6.4. Analysis of Course Objective Attainment

Among the four curriculum objectives, the average achievement degree of curriculum objectives 1-4 in the reform class was about 0.803, 0.796, 0.809 and 0.815,

respectively, and that in the traditional class was about 0.761, 0.757, 0.753 and 0.755, respectively. Curriculum objectives 1 and 2 correspond to basic modeling, structure and stability analysis, and the improvement is relatively mild; curriculum objectives 3 and 4 correspond to control synthesis, engineering simulation and complex problem solving respectively, and the improvement is more obvious, with the effect sizes of 0.660 and 0.706 respectively. The results are consistent with the reform measures: task-driven and run-through simulation does not mainly change students' memory of basic concepts, but strengthens the connection between knowledge, program design and tool application.

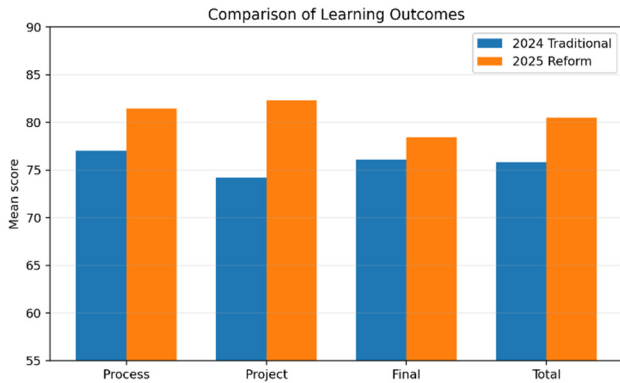


Fig 6. Mean Score Comparison Across Assessment Components and Overall Course Grade

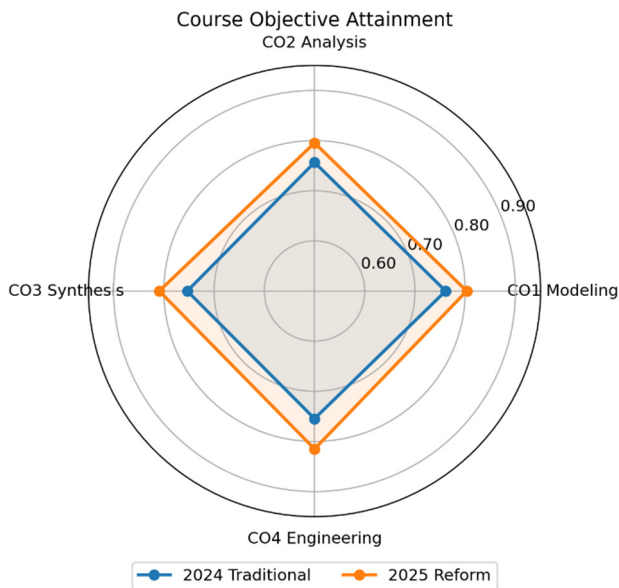


Fig 7. Radar Chart of Course Objective Attainment for the Two Cohorts

The achievement of curriculum objectives can also be used as the basis for the next round of teaching improvement. For example, if the curriculum goal 1 is stable above the target value, and the curriculum goal 2 is low for a long time, it shows that the students can complete the model establishment, but there are difficulties in the interpretation of structural characteristics and the migration of stability theory. Parameter changes, sensor configuration and stability boundary discussion should be added. If the course goal 4 is significantly improved but the course goal 3 is not high, the problem of using software and not designing may occur. It is necessary to strengthen the theoretical relationship between pole selection, control gain and performance index. Therefore,

the value of curriculum objective evaluation is not to get a beautiful radar chart, but to form a closed loop of evaluation-diagnosis-adjustment-re-evaluation.

7. Diversified Assessment and Continuous Improvement Mechanism

7.1. Establishing an Assessment System Integrating Knowledge, Competence, and Learning Process

The evaluation system after the teaching reform follows the principle of being consistent with the curriculum objectives, consistent with the teaching activities, and able to provide evidence for improvement. Process evaluation not only counts the number of attendances and assignments, but also pays attention to whether students continue to complete problem analysis and stage tasks. The project not only checks whether the simulation curve is correct, but also scores from the dimensions of model rationality, theoretical basis, scheme design, code specification, result interpretation and team expression. The final examination retains the necessary theoretical depth of the course, sets a certain proportion of open analysis questions, and avoids weakening the theoretical basis after the evaluation is completely project-based.

7.2. Emphasizing Result Interpretation Rather Than Software Operation

In the MATLAB/Simulink project scoring, the result interpretation is set as an important scoring item. For the two groups that also get the stable curve, if one group can explain the parameter selection from the eigenvalue, pole configuration and control input peak, and the other group only tries repeatedly until the curve looks stable, the results should be significantly different. Through this evaluation orientation, students gradually realize that simulation is not an alternative theory, but is used to verify the theory and support engineering decision-making.

7.3. Refining Teaching Content Based on Assessment Results

At the end of each round of courses, teachers should diagnose from four dimensions: topic score, course objectives, common errors in project reports and student feedback. If the accuracy of controllability calculation at the end of the term is high, but the relationship between actuator position and controllability cannot be explained in the project, it shows that the classroom still focuses on algorithm steps; if the observer program runs correctly but cannot explain the convergence speed of the estimation error, it is necessary to strengthen the pole position and dynamic performance discussion. Through this evidence-based continuous improvement, avoid the curriculum reform into a one-time form.

8. Summary

To meet the requirements of new engineering education for complex engineering problem solving, digital practice and innovative design, a teaching reform framework of linear system theory is proposed to solve the problems of high abstraction of theory, fragmentation of knowledge, lag of simulation application and single assessment method in the teaching of linear system theory. The reform is organized

around four curriculum objectives, and the state space modeling, stability, controllability and observability, state feedback, and state observer design are linked through continuous engineering tasks. MATLAB/Simulink has also changed from an after-school verification tool to an integral part of classroom analysis and design. The inverted pendulum case shows that a continuous engineering situation can link different theoretical topics into a complete problem-solving process. The simulation results further show that the reform is more likely to improve higher-order abilities, especially project performance, control synthesis and engineering simulation, while the improvement of theoretical test scores may not be obvious. Therefore, further work should rely on real teaching data to test the effectiveness of the method in different majors and student groups, so as to promote a broader transformation from knowledge-centered teaching to the coordinated development of theoretical understanding, engineering ability and innovation ability.

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References

- [1] Cao, L., Pan, Y. N., Zhang, L. C., et al. (2026). Teaching reform of "Modern Control Theory" under the background of new engineering. *Western Quality Education*, 12(1), 30–34. (In Chinese)
- [2] Shen, J. Z., Cao, Z. G., Zhu, H. B., et al. (2021). Teaching reform and exploration of "Modern Control Theory" under the background of new engineering. *Journal of Electrical & Electronic Education*, 43(5), 69–73. (In Chinese)
- [3] Ye, Q. (2025). Reflections on the teaching reform of modern control theory from the perspective of new engineering. *Journal of Higher Education*, (8), 130–133. (In Chinese)
- [4] Zhang, Y., & Gao, Y. (2025). Teaching reform of the "Linear Systems Theory" course under the task-driven model. *Western Quality Education*, 11(15), 181–184. (In Chinese)
- [5] Wang, D. (2025). Exploration of the application of artificial intelligence elements in linear systems theory teaching. *Computer Education*, (11), 165–169. (In Chinese)
- [6] Zhao, X. Y., & Wang, Y. X. (2024). Exploration of teaching reform of "Modern Control Theory" in the context of digital intelligence. *The Guide of Science & Education*, (21). (In Chinese)
- [7] Yuan, X. D., Huang, W. N., & He, C. J. (2025). Teaching reform practice of modern control theory oriented toward deep learning. *The Guide of Science & Education*, (28). (In Chinese)
- [8] Zhang, J., Huang, X., Zhong, M. Y., et al. (2025). Exploration and practice of curriculum ideological and political education in the "Linear Systems Theory" course. *Journal of Electrical & Electronic Education*, 47(5), 184–187. (In Chinese)