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Teaching Reform and Practice of College Physics Based on a Four-Dimensional Integrated Teaching Framework

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Abstract: *College physics is a fundamental compulsory course for science and engineering undergraduates to develop scientific literacy and engineering thinking. To solve typical teaching problems including uneven student foundation, abstract physical concepts and insufficient learning motivation, this study constructs a four-dimensional teaching framework consisting of course objective design, teaching process design, multi-dimensional evaluation system and continuous improvement mechanism. This study integrates case teaching, heuristic teaching and flipped classroom teaching to establish a full-cycle teaching management system covering pre-class, in-class and after-class sessions. Ideological and political elements are embedded throughout all teaching links to realize integrated cultivation of knowledge, ability and value guidance. This research offers practical references for college physics teaching reform for science and engineering majors.*

Keywords: *College Physics, Four-Dimensional Teaching Framework, Teaching Reform, Curriculum Ideological and Political Education*

1. Introduction

As a fundamental general course for science and engineering undergraduates, the college physics course undertakes the core task of laying students' theoretical foundations of natural sciences and cultivating their scientific thinking and innovative capabilities[1]. It provides essential theoretical support for undergraduates' subsequent specialized courses and engineering practices. Conventional college physics teaching faces multiple prominent challenges[2], including monotonous teaching modes, separation between theoretical knowledge and practical application, insufficient student participation, and difficulties in accommodating students with diverse academic foundations. Besides, highly abstract physical content and teacher-centered lecturing lead to students' passive learning and insufficient independent exploration.

Against the backdrop of higher education reform, general education courses are required to integrate knowledge delivery and value shaping, making curriculum ideological and political guidance a mainstream reform direction[3]. Most existing teaching optimization schemes only focus on single-dimensional classroom adjustments, while few studies construct a complete integrated reform system covering objectives, teaching procedures, evaluation and cyclic iteration, which creates the research gap to be addressed in this paper[4,5].

To address the problems mentioned above, this paper conducts systematic teaching design and practical exploration across four dimensions: course objectives, teaching processes, evaluation, and continuous improvement. An integrated teaching system combining knowledge transmission, ability cultivation and value guidance is constructed, taking the closed-loop continuous improvement mechanism as its core innovation to boost the overall teaching quality of college physics.

2. Course Objective Design

Course objectives act as the core guiding principle for teaching activities, and all teaching design and implementation are carried out around these objectives. In alignment with the undergraduate talent training program for science and engineering majors, this course constructs an objective system covering knowledge acquisition, practical competence, personal development and value shaping, as shown in

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Figure 1.

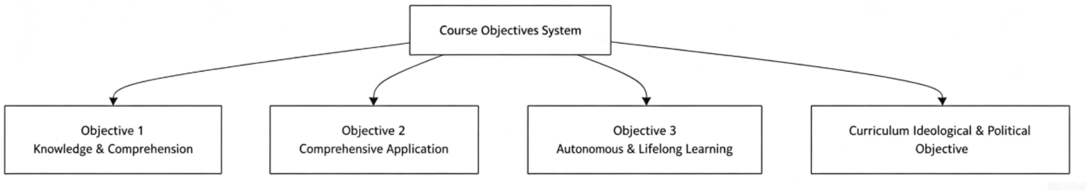

Figure 1: Design of the course objectives system.

2.1. Knowledge and Comprehension Objective

Students are expected to accurately describe the basic concepts, physical principles and fundamental laws involved in college physics. They can identify typical physical phenomena, interpret their internal mechanisms, and deduce logical conclusions based on physical theories, so as to establish a complete and coherent theoretical knowledge system of college physics.

2.2. Comprehensive Application Objective

Students can apply the physical knowledge, theoretical models and analytical methods learned in this course to analyze and solve practical problems. By combining physical theories with engineering scenarios, students will strengthen their capability to solve practical problems with theoretical knowledge and gradually form systematic engineering thinking.

2.3. Autonomous and Lifelong Learning Objective

Students can utilize scientific learning methods acquired in this course to handle learning tasks in subsequent professional courses and future career practices. They will develop independent learning capabilities and establish a clear awareness of lifelong learning to adapt to technological advances and long-term career development.

2.4. Ideological and Political Education Objective

Guided by the fundamental task of fostering virtue through education, this course integrates course ideological and political elements into the whole teaching process with clear value-oriented objectives. While learning physical theories, students cultivate scientific spirit, scientific thinking and patriotism. Moreover, the course guides students to develop a correct worldview, outlook on life, and values.

3. Teaching Process Design

The teaching process acts as the core carrier to achieve the course educational objectives. This study constructs an integrated teaching system supported by three modules: diversified teaching approaches, full-process teaching management, and in-depth curriculum ideological and political education. The overall structural framework of this teaching process design is shown in Figure 2.

3.1. Diversified Teaching Approaches

Given the high abstraction of college physics, the single lecture-based teaching mode is replaced by a combination of case-based teaching, heuristic teaching and flipped classroom teaching, with value guidance embedded into all classroom sessions to improve student participation and learning efficiency.

3.1.1. Case-Based Teaching

This mode bridges abstract physical theories with daily scenarios, engineering practice and cutting-edge technologies via targeted teaching cases. For instance, momentum theorem adopts water jet cutting and rocket launch engineering cases; thermodynamics relies on automobile engine cycles to analyze thermal efficiency optimization. Combined with situational video materials, the design helps students perceive the practical value of physical knowledge and cultivate engineering awareness.

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3.1.2. Heuristic Teaching

Following the logic of “problem introduction, guided inquiry, collaborative discussion, knowledge construction”, progressive questioning drives independent exploration. Taking Galileo’s falling body experiment as the entry point, layered questions on object motion inspire students to revisit classic physical experiments and deduce kinematic formulas autonomously, fostering scientific inquiry and critical thinking capabilities.

3.1.3. Flipped Classroom Teaching

Supported by online teaching platforms, pre-recorded explanatory videos are assigned for self-directed preview before class. In-class time is fully reserved for difficult-concept elaboration, case analysis and group engineering discussions, forming a closed-loop learning chain: pre-class self-study, in-depth classroom inquiry, and post-class consolidation. The model optimizes classroom efficiency and reinforces students’ autonomous learning competency.

3.2. Full-Process Teaching Management

A three-stage whole-process management mechanism covering pre-class, in-class and post-class sessions is established to track learning progress dynamically, match the implementation of diversified teaching approaches, and deliver targeted personalized tutoring.

3.2.1. Pre-class Management

The core goal is to lay a solid preview foundation for the flipped classroom. Teachers release preview videos and electronic courseware via online platforms for students to sort out key and difficult knowledge points. Submitted preview assignments enable teachers to identify learning gaps and adjust in-class teaching content and pace accordingly.

3.2.2. In-class Management

Interactive classroom activities are deployed to monitor real-time learning engagement, including opening mini-quizzes, collaborative physics problem discussions and chapter unit tests. Short quizzes check preview quality; group debates deepen physical understanding; chapter tests promptly detect knowledge loopholes and support instant targeted guidance.

3.2.3. Post-class Management

Three-tiered after-class assignments, structured chapter mind-map tasks and all-time online tutoring constitute post-class support. Tiered exercises adapt to students with different academic levels; mind maps guide systematic knowledge sorting; online platforms and instant messaging tools provide round-the-clock Q&A and one-on-one remediation for underperforming students.

3.3. In-depth Integration of Course-Based Ideological and Political Elements

Ideological and political cultivation is embedded into every segment of pre-class preview, in-class teaching activities and post-class training, unfolding along three core dimensions to realize knowledge delivery and value shaping.

3.3.1. Cultivation of Scientific Spirit

Combining physics history and physicist stories, the design advocates the spirit of questioning, truth pursuit and continuous innovation. Taking classical mechanics and relativity teaching as examples, scholars’ persistent exploration journeys help students recognize that scientific progress originates from long-term independent inquiry.

3.3.2. Cultivation of Scientific Thinking

Physics knowledge instruction is matched with skill training to develop multi-dimensional scientific reasoning. For core modules including Lorentz transformation and thermodynamic cycles, mathematical derivation, inductive analysis and case reasoning are adopted to standardize students’ logical thinking and problem-solving frameworks for engineering challenges.

3.3.3. Value-Oriented Patriotic Education

Domestic major science-and-technology breakthroughs are integrated with physical knowledge to cultivate patriotism and social responsibility. Conservation of momentum combines Long March carrier

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rocket launch cases; relativity and nuclear physics introduce domestic advanced research achievements. Such real national engineering cases stimulate learning motivation and foster students' aspiration to contribute to national technological development.

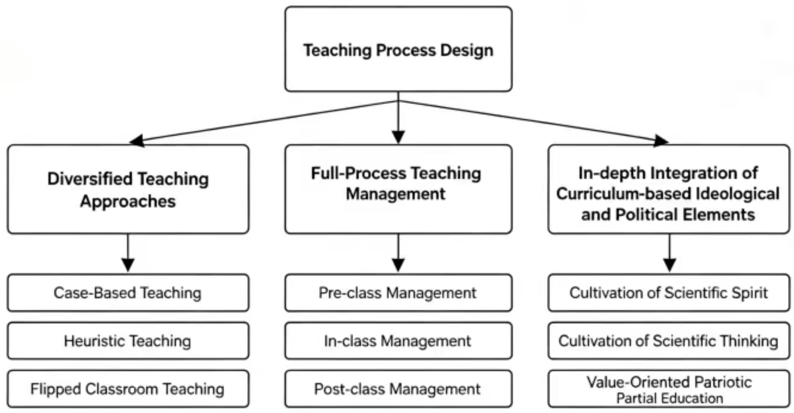

Figure 2: Framework of the Teaching Process Design System.

4. Teaching Evaluation Design

To address the limitations of the traditional single final-exam assessment, this course builds a full-cycle diversified evaluation framework integrating formative assessment and summative assessment with equal weight. Supported by bidirectional feedback between students and teachers, the system realizes comprehensive, objective measurement of students' academic performance, comprehensive ability, and ideological literacy, forming a closed-loop logic: teaching implementation, multi-dimensional evaluation, targeted optimization.

4.1. Construction of Diversified Evaluation System

The total course grade is equally divided into formative assessment and summative assessment, each accounting for 50%, as shown in Table 1. This weight scheme emphasizes full-cycle process evaluation and shifts students' focus to daily learning accumulation. Evaluation indicators for scientific spirit and patriotism are embedded in formative tasks to simultaneously assess knowledge, ability and value shaping.

Table 1: Composition and Weight Distribution of the Course Evaluation System.

Evaluation Category	Formative Assessment					Summative Assessment
	In-class Performance	After-class Homework	Chapter Summary	Chapter Quizzes	Mid-term Examination	Final Examination
Weight	10%	10%	10%	10%	10%	50%

4.1.1. Formative Assessment

Formative assessment tracks students' complete learning cycle covering pre-class preparation, in-class interaction and post-class consolidation, with five balanced sub-dimensions each occupying 10% of the total grade.

(1) In-class performance: Measure classroom engagement, collaborative discussion performance and critical inquiry awareness.

(2) After-class homework: Inspect students' consolidation of core physical theories and standardization of problem-solving logic.

(3) Chapter summary: Ask students to organize chapter knowledge into one-page mind maps for systematic knowledge induction.

(4) Chapter quizzes: Timely detect knowledge loopholes after chapter learning.

(5) Mid-term examination: Conduct phased comprehensive detection of chapter knowledge and

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preliminary engineering application capabilities.

4.1.2. Summative Assessment

The summative assessment takes the form of a closed-book final exam covering all core physical knowledge of the course. It focuses on evaluating students' theoretical comprehension, scientific reasoning and engineering application capabilities, and objectively measures their overall command of course knowledge and ability to apply physics theories to solve complex practical problems.

4.1.3. Flipped Classroom Teaching

With online teaching platforms, pre-recorded lecture videos are assigned for pre-class self-preview. In-class time is fully reserved for difficult-concept elaboration, case analysis and group discussions, forming a closed learning loop: pre-class self-study, in-class inquiry, and post-class consolidation. This model optimizes classroom efficiency and reinforces students' autonomous learning ability.

4.2. Feedback and Iterative Application of Evaluation Results

A standardized bidirectional feedback mechanism is established to transmit assessment data to both students and teachers promptly, which drives targeted improvement of student learning and continuous optimization of classroom teaching.

4.2.1. Feedback for Students

After grading all formative tasks and the mid-term exam, teachers publish assessment results instantly via online platforms. Two-tiered targeted guidance is implemented: common learning obstacles are analyzed collectively in class, while individual knowledge gaps are addressed through online Q&A and one-on-one tutoring. With formative assessment records, students can clearly locate their weak points from preview, in-class activities and after-class exercises, make targeted plans, and gradually develop autonomous error-correction and lifelong learning capabilities.

4.2.2. Feedback for Teachers

Through systematic statistical analysis of full-cycle evaluation data, teachers grasp the class's overall learning status, including common difficult knowledge points and students' reception of diverse teaching modes. Based on assessment feedback, teachers dynamically adjust teaching plans: supplementary engineering cases and layered exercises are added for poorly mastered knowledge; heuristic and flipped teaching are adopted for low-participation classes. Such data-driven modifications realize iterative optimization of all teaching links.

Table 2: Composition and Weight Distribution of the Course Evaluation System.

Module	Course Objective	Assessment Content	Target Score
Quantitative Evaluation	Objective 1: Knowledge & Comprehension	In-class Performance	5
		After-class Homework	3
		Chapter Quizzes	4
		Chapter Summary	5
		Mid-Exam (Objective 1 Part)	6
		Final Exam (Objective 1 Part)	25
	Objective 2: Comprehensive Application	In-class Performance	4
		After-class Homework	6
		Chapter Quizzes	4
		Mid-Exam (Objective 2 Part)	4
		Final Exam (Objective 2 Part)	25
	Objective 3: Autonomous & Lifelong Learning	In-class Performance	1
		After-class Homework	1
		Chapter Quizzes	2
		Chapter Summary	5
Qualitative Evaluation	Ideological and Political Education Objective	Questionnaire	-

This research splits the entire evaluation system into quantitative and qualitative modules. The quantitative evaluation serves the first three learning objectives with graded scoring criteria, while

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questionnaires are adopted for qualitative assessment of curriculum ideological and political literacy. Detailed matching rules for evaluation dimensions and score weights are listed in Table 2.

Based on the multi-dimensional scoring criteria listed in Table 2, the objective attainment degree can be quantified by the weighted summation formula shown below:

$$\text{Objective Attainment Degree} = \sum \text{Item Weight} \times \frac{\text{Item Average Score}}{\text{Item Target Score}}$$

In this formula, Item Weight refers to the proportional weight of each assessment item under corresponding course objectives; Item Average Score represents the average score students obtained in each assessment task; Item Target Score denotes the full score assigned to each assessment item. After calculating the annual attainment value of each objective, the three-year variation trend of objective attainment is illustrated in Figure 3, which represents a consistent yearly upward trend of course objective attainment and validates the positive effect of teaching optimization. To sustain steady improvement in teaching quality, this study constructs a closed-loop continuous improvement mechanism, which will be elaborated in Section 5.

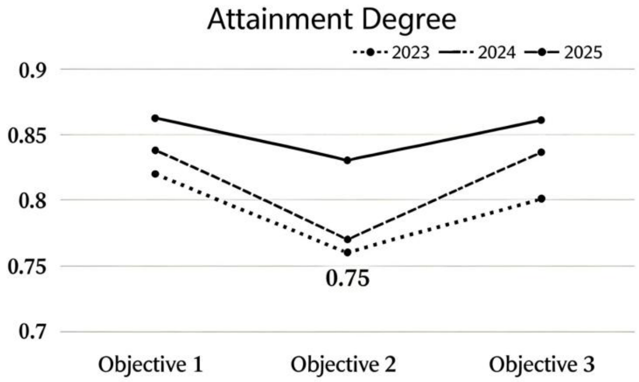

Figure 3: Trend of Course Objective Attainment Degree (2023-2025).

5. Continuous Improvement Mechanism

Supported by the diversified teaching design and multi-dimensional evaluation system mentioned above, this college physics course establishes a closed-loop continuous improvement mechanism covering the full teaching cycle, as illustrated in Figure 4. Multi-source feedback data are integrated to identify gaps between practical teaching outcomes and predefined learning objectives, enabling iterative targeted revision of all teaching segments.

5.1. Multi-dimensional Collection of Improvement Information

Four complementary channels are constructed to collect quantitative and qualitative evidence for teaching optimization, including objective assessment data, student feedback, peer evaluation and professional training requirements. Ideological and political literacy is taken as a consistent observation indicator across all channels.

5.1.1. Analysis of Teaching Assessment Results

Formative and summative assessment data in Section 4 generate objective learning profiles of students. Statistical analysis of score distribution, error-prone knowledge points and unit mastery helps teachers to accurately locate universal learning difficulties and defects in teaching arrangement, laying a quantitative foundation for targeted improvement.

5.1.2. Collection of Students' Learning Feedback

Multiple interactive approaches, including online questionnaires, classroom seminars, and offline after-class talks, are adopted to gather students' opinions on preview assignments, classroom teaching, layered exercises and tutoring support. Combined with students' feedback on scientific literacy and patriotic engineering cases, teachers identify personalized learning demands and adjust teaching plans accordingly.

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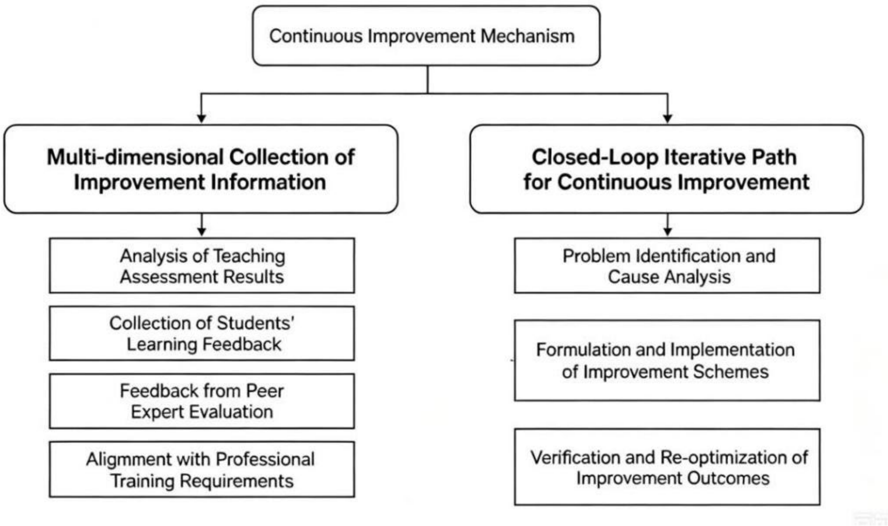

Figure 4: Framework of Continuous Improvement Mechanism for Course Teaching.

5.1.3. Feedback from Peer Expert Evaluation

Professional teachers and teaching experts are invited to observe and evaluate classroom teaching. Peer comments focus on the rationality of teaching design, student-centered teaching effects, and implicit ideological and political infiltration. Teachers draw on advanced teaching experience and optimize classroom implementation schemes based on expert suggestions.

5.1.4. Alignment with Professional Training Requirements

Through regular communication with directors and teachers of various engineering majors, the physical knowledge and scientific thinking abilities required for subsequent specialty courses are clarified. By analyzing the matching degree between teaching content and talent training objectives, core knowledge points and engineering cases can be dynamically revised to satisfy differentiated cultivation requirements of diverse disciplines.

5.2. Closed-Loop Iterative Path for Continuous Improvement

Based on multi-source integrated feedback data, the course adopts a standardized three-stage closed-loop workflow: problem identification and root-cause analysis, formulation and implementation of improvement schemes, and verification and re-optimization of reform outcomes. This workflow forms a spiral upward circulation for iterative teaching optimization.

5.2.1. Problem Identification and Cause Analysis

Cross-analysis of multi-dimensional feedback data helps teachers pinpoint deficiencies in classroom teaching and trace their underlying root causes. Common defects include insufficient integration of physical theories and engineering scenarios, students’ weak independent inquiry ability, and inadequate implicit ideological-political guidance. Corresponding root factors are classified to rank the priority of subsequent improvement measures, such as monotonous teaching forms and shallow expansion of ideological cases.

5.2.2. Formulation and Implementation of Improvement Schemes

Targeted and operable improvement plans are formulated according to sorted teaching defects and fully embedded into diversified teaching links proposed in Section 3. Take insufficient autonomous learning ability as an instance: layered preview guides, heuristic and flipped inquiry tasks, and tiered homework jointly realize progressive knowledge consolidation. Supplementary patriotic engineering cases and physicists’ research stories are integrated to cultivate students’ scientific spirit and patriotism. All revised improvement schemes are fully applied in subsequent teaching sessions.

5.2.3. Verification and Re-optimization of Improvement Outcomes

After full-cycle implementation of improvement schemes, the multi-dimensional evaluation system proposed in Section 4 is adopted to assess reform effects comprehensively. Multiple indicators including

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academic performance, classroom engagement and student feedback are measured to verify if revised teaching links match preset course objectives. Valid adjustment measures are integrated into standardized teaching systems. Unsatisfactory schemes will undergo root-cause reanalysis, plan revision, and repeated closed-loop iteration to reach targeted learning and value cultivation outcomes.

6. Conclusions

This study addresses typical drawbacks of traditional college physics teaching and constructs a multi-dimensional integrated course framework consisting of four core modules: course objective design, classroom teaching design, multi-dimensional evaluation system, and closed-loop continuous improvement mechanism. Diversified teaching strategies and full-cycle classroom management are deployed. Curriculum ideological-political guidance is embedded in all teaching segments, while unified quantitative and qualitative evaluation criteria are formulated. Supported by this framework, the teaching mode shifts from teacher-centered cramming to student-centered independent inquiry, balancing three cultivation targets: knowledge mastery, practical competency and value shaping. Three years of classroom data verify the reform efficacy, resolving persistent teaching defects including insufficient learning motivation, weak knowledge foundation, and separation between physical theories and engineering practice. The yearly growth of course objective attainment demonstrates students' overall advancement in learning passion, theoretical command, problem-solving capability and autonomous learning. Meanwhile, embedded ideological activities cultivate students' rigorous scientific thinking, patriotic awareness and engineering literacy.

Centered on virtue education, this research puts forward iterative optimization directions for follow-up work. The four-dimensional course system and closed-loop improvement mechanism will be refined in subsequent studies to deepen the integration of college physics and specialized engineering courses. Future adjustments will adapt teaching content to differentiated talent cultivation demands of various engineering majors, cultivating innovative engineering talents with solid physical literacy.

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