ISSN 2522-6398 Vol. 9, Issue 8: 1-7, DOI: 10.25236/FER.2026.090801

Teaching Reform and Practice of College Physics Experiment Course

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Abstract: *As a compulsory general education course for science and engineering undergraduates, the college physics experiment course faces typical teaching dilemmas, including separation between theoretical knowledge and experimental practice, and low student engagement. This paper constructs a three-dimensional teaching framework covering three aspects: course positioning and value orientation, course operation and management, and course characteristics and innovation. Diversified resource platforms, full-process closed-loop management mechanisms and online-offline blended teaching modes are established to integrate curriculum ideological and political education into all experimental teaching sessions. The proposed system improves teaching quality and provides practical references for experimental course reform in colleges and universities.*

Keywords: *College Physics Experiment, Teaching Reform, Practical-Oriented Teaching, Curriculum Ideological and Political Education*

1. Introduction

College physics experiment is a compulsory foundational general-education experimental course for undergraduates majoring in science and engineering. It serves as a key bridge connecting students' theoretical knowledge with practical innovation, and plays an irreplaceable role in cultivating students' scientific literacy, experimental skills, innovative thinking and engineering practical abilities[1,2]. Nevertheless, traditional college physics experiment teaching suffers from obvious defects such as monotonous teaching modes, disconnection between theory and practice, students' passive learning, and so on. Furthermore, the educational function of the course has not been fully fulfilled since teaching overly emphasizes skill-oriented training while neglecting the cultivation of students' scientific spirit, innovative thinking, sense of responsibility and patriotism[3,4].

Taking the college physics experiment course as the research object, this paper considers its general-education positioning and talent-training requirements of science-and-engineering majors. It constructs systematic teaching-reform research and practical exploration from three dimensions, namely curriculum positioning and value, curriculum operation and management, as well as curriculum characteristics and innovation. A complete and implementable teaching system for college physics experiment course is established, which effectively improves the teaching quality and student-cultivating outcomes. It also offers practical references for science-and-engineering majors in colleges and universities.

2. Design of Course Objectives

Guided by the talent cultivation requirements for science and engineering majors, this course conducts targeted design of course objectives and constructs a dual-objective system. This system includes hierarchical competency objectives and quality-oriented educational objectives. The former contains three progressive objectives, i.e., knowledge and comprehension, comprehensive application, and autonomous lifelong learning. The latter covers curriculum-based ideological-political education and lab safety education, which is an indispensable basic requirement for physics experimental teaching. The dual-objective system fully complies with the graduation requirement indicators specified in the undergraduate professional training program.

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2.1. Hierarchical Competency Objectives

2.1.1. Knowledge and Comprehension Objective

Students are expected to list the foundational knowledge of this course and explain it accurately. They will master the basic physical principles, experimental methods, and standard operational specifications of experiments. In this way, students can develop basic laboratory operation competency.

2.1.2. Comprehensive Application Objective

Students will proficiently apply experimental knowledge, methods and skills acquired in this course to design and conduct scientific experiments independently. They can also develop the ability to analyze and solve practical problems encountered in experimental operations.

2.1.3. Independent and Lifelong Learning Objective

Students will master scientific learning methodologies and experimental thinking modes learned in this course. They can apply such competencies proficiently to subsequent courses, future academic research and professional careers. Students will develop autonomous learning capabilities and lifelong learning awareness, so that they can adapt to evolving technological advances and career demands in the future.

2.2. Quality-oriented Educational Objectives

This course formulates two clear objectives for ideological-political education and lab safety education, to realize integrated development of value guidance and knowledge delivery.

2.2.1. Ideological-Political Education Objective

By participating in a series of experimental training sessions, students will cultivate scientific spirit, innovative thinking, and patriotism. This course helps students develop a realistic scientific attitude and the exploratory spirit of continuous experimental exploration, as well as the belief of serving the country through scientific and technological innovation.

2.2.2. Safety Education Objective

Whole-process standardized laboratory management enhances students' awareness of safety regulations, risk prevention, accountability and self-discipline. Guided by the experimental philosophy of "safety first, standardized operation", students will strictly abide by lab norms, and cultivate a solid sense of responsibility and professional literacy specific to physics experiments.

As shown in Figure 1, a complete dual-objective training framework for college physics experiment courses is constructed, which consists of hierarchical competency objectives and quality-oriented educational objectives covering ideological-political education and safety education.

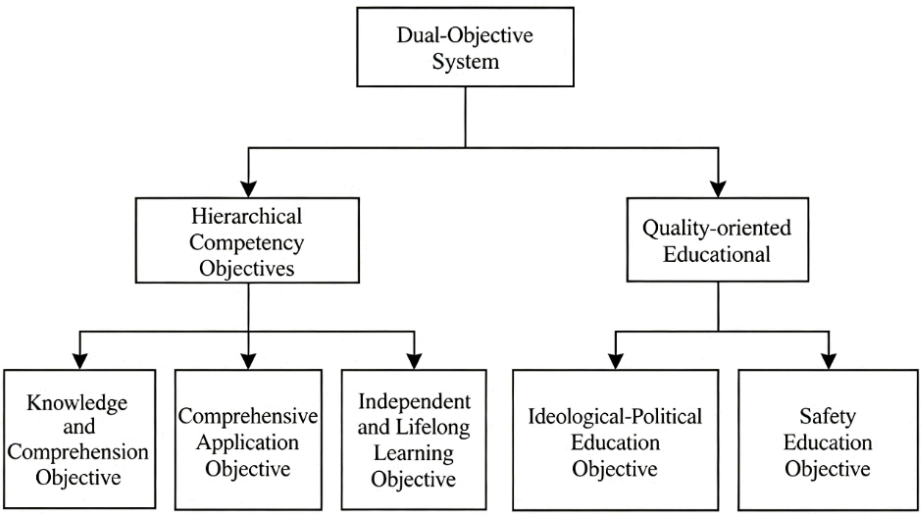

Figure 1: Framework of the Dual-Objective Course Target System for College Physics Experiment.

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3. Course Operation and Management

3.1. Full-Process Teaching Operation Arrangement

This course constructs a full-process teaching operation system covering timetable arrangement, course selection execution and whole-process management, aiming to guarantee stable, efficient and orderly teaching implementation.

3.1.1. Basic Timetable Scheduling Management

With the support from the college's online academic administration system, the teaching team completes basic course data entry and timetable arrangement. A detailed teaching calendar is then compiled. It covers teaching schedules, experimental projects, which lays a solid foundation for orderly teaching implementation.

3.1.2. Course Selection Implementation Management

The online physics-experiment platform acts as the core hub for online course selection, timetable adjustment and process management. A phased course selection model is designed, including unified scheduling of mandatory experiments and two rounds of independent optional experiment selection for students. This model realizes end-to-end data transmission and execution, and accurately matches experimental resources with the learning demands of each student.

3.1.3. Cross-System Collaborative Management

A multi-level collaborative notification system is established to ensure full coverage of students' course selection information. The system involves the physics experiment online platform, theoretical course teachers, class monitor groups, and student groups who need to retake the course. It ensures that all students can receive course selection notifications timely. After practical implementation, the semester's overall course selection coverage rate reaches 99.9%. Furthermore, a real-time response mechanism is set up to address students' inquiries related to course selection. All consultation problems are resolved within 24 hours with a 100% resolution rate, which effectively supports the smooth progress of teaching activities.

3.2. Diversified Construction of Course Resources

Traditional physics experimental teaching mostly relies on fixed offline labs, which brings obvious drawbacks such as limited student operation time, high consumable costs and insufficient after-class extended training channels. To break the limitation of time and venue and support multi-dimensional student competency cultivation, this course follows the student-centered teaching philosophy and constructs an integrated three-dimensional experimental teaching resource system, which consists of offline physical experiments, virtual simulation experiments, and home-based extended experimental projects. The system provides students with full-scenario support for experimental practice.

3.2.1. Development of Offline Physical Experimental Projects

Offline physical experiments serve as the core component of in-class teaching, which are classified into three categories: verification experiments, comprehensive experiments, and design-oriented experiments. These experiments cover five major physics modules, i.e., mechanics, thermodynamics, electromagnetism, optics and modern physics. Meanwhile, standardized experimental teaching spaces are built, including interactive teaching zones and hands-on operation zones equipped with standardized experimental instruments and workbenches. Teaching activities are implemented through a hybrid mode that combines centralized lectures and group hands-on operations. The cloud-based textbook *College Physics Experiment Tutorial* is provided as systematic experimental guidance to guarantee high-quality offline experimental teaching.

3.2.2. Development of Virtual Simulation Experimental Projects

Supported by modern information technology, a virtual simulation experiment platform is developed. Consistent with offline resources, these virtual items cover the same three experiment types and five core physics modules mentioned above. Adopting a virtual-real integrated mode, the platform reproduces the complete instrument connection and operation process at a 1:1 scale, and delivers real-time dynamic feedback of experimental data and physical phenomena. This mode effectively eliminates temporal and spatial constraints and reduces the consumption of experimental consumables, allowing students to repeat hands-on training flexibly anytime. The supporting manual *Guidance for*

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Virtual Simulation Experiments serves as a complement to offline teaching and further enriches the overall course resources.

3.2.3. Development of Home-Based Experimental Projects

To expand experimental teaching scenarios and strengthen the connection between physical theories and daily life, home-based experimental items are developed, including verification, comprehensive and design-oriented experiments covering mechanics, thermodynamics and optics modules. Different from professional laboratory facilities, these home-based experiments adopt daily supplies and portable mobile acquisition devices, realizing accessible experimental practice that can be carried out anywhere at any time. This model removes venue restrictions and guides students to recognize that physical laws originate from daily life.

3.3. Closed-Loop Organization of Practical Teaching

This course establishes a full-process closed-loop practical teaching framework covering pre-class preview, in-class operation, and post-class report writing. A hybrid online-offline teaching model is developed, and a multi-dimensional evaluation system covering the whole learning process is built to guarantee high-quality experimental teaching.

3.3.1. Full-Process Closed-Loop Teaching

Practical teaching follows a standardized workflow, namely pre-class theoretical preview, in-class experimental operation and verification, and post-class data processing and analysis. Before class, students are guided to master relevant experimental principles and submit preview assignments in advance. During class, teaching activities focus on experimental operation, phenomenon observation, and data acquisition. Teachers provide on-site guidance to resolve students' difficulties in a timely manner. After class, students are required to process experimental data independently and write standardized formal experimental reports. This complete closed-loop workflow improves students' hands-on experimental skills and cultivates rigorous research attitudes.

3.3.2. Online-Offline Integrated Teaching Support

Supported by the online teaching platform *Cloud Class*, blended teaching that integrates online resources and offline hands-on practice is implemented. Before class, preview materials, lecture slides and micro-lesson videos are released on the platform to facilitate students' autonomous pre-learning. During class, online tools are applied for real-time classroom interaction, instant quizzes and group discussions, which helps teachers keep track of students' learning progress promptly. After class, the platform is used to release requirements for experimental reports, correct submitted assignments and provide long-term Q&A tutoring. Deep integration of online and offline teaching significantly improves the overall teaching efficiency of experimental courses.

3.3.3. Full-Coverage Multi-Dimensional Evaluation

Breaking the limitation of the traditional single assessment mode that only judges students by final exam scores, this study establishes a multi-dimensional evaluation system combining formative and summative assessment, covering the complete cycle of students. Formative assessment evaluates students' learning performance based on pre-class preview, in-class operation and post-class report. Summative assessment mainly adopts a comprehensive final experiment test to examine students' abilities in experimental operation, data processing and problem analysis. In addition, the teaching team develops unified assessment criteria and detailed scoring rubrics for experiment reports to ensure objective evaluation. This mechanism encourages students to value the whole learning process instead of only focusing on final exam scores.

4. Course Characteristics and Innovations

4.1. Construction of an Innovative Experimental Teaching System

Traditional college physics experiment teaching is often confined to in-class laboratory operation, with insufficient channels for students' after-class innovative practice. However, there is a clear disconnect between classroom teaching, discipline competitions and undergraduate research training. To break such limitations, this course follows the educational philosophy integrating in-class instruction and extracurricular practical innovation, and establishes an innovative physics experimental

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teaching system with the framework of "one main body and two wings". In this system, in-class experimental teaching acts as the core body, while platform expansion and extracurricular practical innovation serve as its two supporting wings. The formed teaching model realizes deep integration of in-class and extracurricular activities, theory and practice, as well as knowledge learning and innovative application.

In terms of course system arrangement, a multi-layered and multi-module framework is adopted. Experimental projects are classified into three tiers: basic verification experiments, comprehensive design experiments, and innovative research experiments. These projects cover five core physics modules, namely mechanics, thermodynamics, electromagnetism, optics and modern physics. Such a setting can accommodate undergraduates from different majors with diverse academic foundations. Furthermore, a virtuous cycle linking experimental teaching, discipline competitions, and scientific research has been constructed. Centered on experimental classroom teaching, the system provides students with platforms to participate in discipline competitions and undergraduate research practices. It encourages students to apply knowledge and skills learned in laboratory classes to competitions and research. Meanwhile, new theories, experimental methods and technical achievements generated from competitions and research are fed back to experimental teaching, which helps update teaching contents continuously and reform instructional methods, as shown in Figure 2. Eventually, deep integration between teaching and research is formed, and this mechanism effectively cultivates students' innovative thinking and hands-on practical abilities. The number of students participating in disciplinary competitions has risen continuously in recent years, which reflects the positive incentive effect of the proposed experimental teaching system on students' innovative practical abilities, as illustrated in Figure 3.

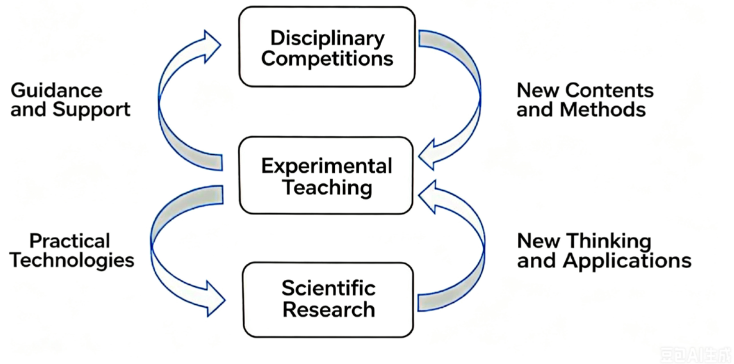

Figure 2: Virtuous iteractive cycle framework of experimental teaching, competitions and research.

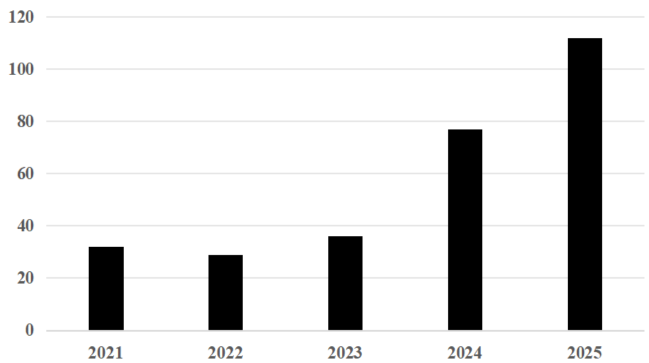

Figure 3: Annual growth trend of teaching reform effectiveness indicators (2021-2025).

4.2. Development of Digital New-Form Textbooks and Teaching Resource System

Guided by the educational concept that digital technology reshapes textbook construction modes, this course keeps pace with the upgrading of teaching materials by deeply integrating diversified course resources with cutting-edge information technology. It breaks the closed boundaries of traditional printed textbooks and builds a diversified, three-dimensional innovative digital textbook system for undergraduates.

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In this course, the scope of teaching materials is no longer limited to printed textbooks. It covers a full range of teaching resources including courseware, teaching plans, cloud textbooks, micro-lesson videos, teaching schedules, online learning materials, and demonstration experiments. These resources jointly constitute a complete teaching resource ecosystem. The teaching team regularly optimizes and updates teaching contents by incorporating the latest research outcomes, integrating state-of-the-art technological advances into textbooks and supporting materials. In this way, teaching resources remain timely, innovative and practical. Meanwhile, the whole digital resource system provides students with comprehensive full-process learning support, effectively improving their experimental learning experience and overall academic performance. The composition of this diversified teaching resource system is illustrated in Figure 4.

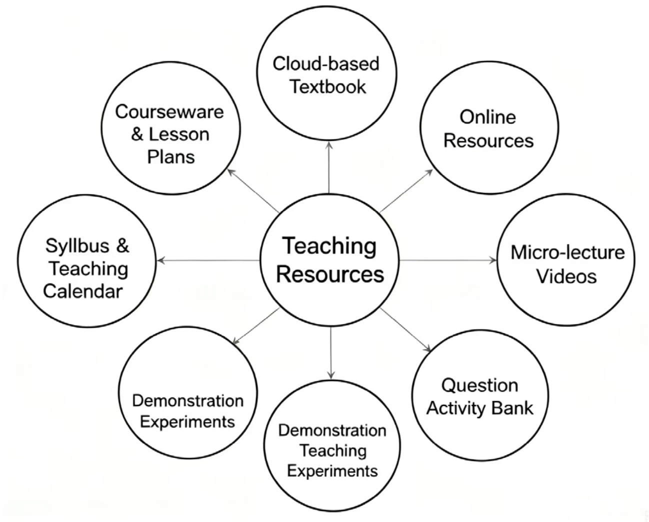

Figure 4: New Category of Course Teaching Materials.

4.3. Developing an Information-Driven Teaching Framework to Enable Pedagogical Innovation

To reshape students' learning environments with state-of-the-art educational technologies, this study builds a comprehensive informatized teaching framework for college physics experiments, with the core objective of advancing pedagogical innovation.

The digital teaching ecosystem is anchored around cloud textbooks, cloud classrooms, microlecture resources, experiment scheduling management modules, and virtual simulation experiment platform. This integrated ecosystem is structured as an interconnected suite, namely an online physics experiment portal, cloud teaching materials, cloud interactive classrooms, and virtual simulation experiment platform. Collectively, it enables end-to-end digital oversight and governance across the entire lifecycle of teaching activities.

Supported by cloud classrooms, an online-offline blended teaching framework is implemented to facilitate digital management of pre-class preparation, in-class engagement and post-class tutoring, which in turn elevates overall teaching efficiency. The virtual simulation platform advances the digital transformation of experimental teaching. It breaks temporal and spatial limitations of traditional laboratory teaching and expands accessible hands-on practice for students. Meanwhile, the experiment scheduling and management system streamlines administrative workflows, aligning limited experimental resources with students' personalized learning goals and boosting both the efficiency and granularity of teaching administration.

The development of this information-driven framework delivers a fundamental shift in instructional philosophy. The traditional teacher-centered lecture model is replaced by personalized, diversified student-centered learning designs. This transition fosters students' intrinsic motivation to learn independently and nurtures their creative thinking and innovative problem-solving skills.

5. Conclusions

This study conducted systematic teaching reforms and practical explorations on college physics

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experiment courses, which effectively improved the overall teaching quality of the curriculum. In practice, the teaching team conducted a closed-loop mechanism, in which theoretical research outcomes guide continuous optimization of classroom teaching. Meanwhile, the compilation of cloud textbooks, experimental tutorials and handbooks for virtual experiments has enriched the curriculum’s teaching resource system. The training schemes updated in this reform have greatly improved students’ experimental operational skills, innovative thinking and comprehensive literacy. Under teachers’ guidance, students won various honors in national and provincial discipline competitions, such as awards from the National College Students’ Physics Experiment Competition and digital innovation contests, which verifies the effectiveness of the reform in talent cultivation. The proposed reform framework can provide replicable practical references for the experimental teaching renovation of other engineering and science majors in the college. Additionally, the team promoted academic exchanges by inviting external experts to deliver thematic lectures and share reform insights, realizing the exemplary and promotional value of this teaching practice.

In future work, we will further deepen the teaching reform from multiple dimensions. We intend to refine teaching contents and instructional designs, further integrate information technology with physical experiment teaching, and establish a high-quality online-offline blended teaching system. Moreover, we will embed professional ethics education, scientific spirit cultivation and patriotism education into the whole process of experimental teaching through curriculum ideological and political construction. Nevertheless, this research has certain limitations such as relatively short implementation cycles and limited sample scales. In follow-up research, we will expand the scope of reform implementation and carry out long-term tracking assessments to cultivate high-quality innovative talents for engineering disciplines.

Acknowledgements

This work was supported by the 2025 Teaching Reform Special Project for Smart Curriculum Construction, Beijing Institute of PetroChemical Technology (Grant No. XNPSZHKC202507003).

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