Frontiers in Educational Research
ISSN 2522-6398 Vol. 9, Issue 4: 29-33, DOI: 10.25236/FER.2026.090405

Research on Application-Oriented Teaching Reform of College Physics Experiment under the Background of "Classroom Revolution"

Xiaomei Li[a]

Institute of Fundamental and Interdisciplinary Sciences, Beijing Union University, Beijing, 100101, China
[a]lixiaomei@buu.edu.cn

Abstract: *Traditional college physics experiment courses emphasizes verification over application, which makes it difficult to meet the talent training needs of "New Engineering" and "New Science". Taking "student-centered, problem-driven, practical innovation" as the core concepts, this study constructs a three-level "foundation-comprehensive-innovation" curriculum system, supported by diversified teaching methods and literacy-oriented evaluation mechanisms. Practice shows that the proposed reform has significantly improved students' experimental skills and innovative capabilities, providing a replicable practical path for the teaching reform of similar courses.*

Keywords: *Classroom Revolution, Physics Experiment, Teaching Reform*

1. Introduction

Against the background of "Classroom Revolution" and the construction of New Engineering and New Science, the drawbacks of traditional college physics experiment courses, such as "emphasizing verification over application, and theory over practice", have become increasingly prominent. These issues make it difficult to meet the demand for cultivating high-quality applied and innovative talents in the new era. Guided by the core concepts of "student-centered, problem-driven, practical innovation", this study systematically explores and implements teaching reform in college physics experiment courses. It aims to establish a physics experiment teaching system which adapts to the development of the times and improve students' comprehensive abilities and literacy.

2. Curriculum System Reconstruction: A Three-Level Module Framework

2.1 Objective Orientation

The overall goal of this curriculum system reconstruction is to achieve the deep integration of physics knowledge teaching with scientific thinking, practical ability and innovative literacy. Such integration enables the cultivation of high-quality compound talents who can adapt to the development needs of New Engineering and New Science, with the ability to solve complex engineering and scientific problems[1]. The specific objectives include knowledge objectives, ability objectives and literacy objectives. For knowledge objectives, efforts should be made to consolidate the basic theoretical knowledge of physics experiments and construct an interdisciplinary knowledge integration system. For ability objectives, it is necessary to improve basic experimental operation skills, strengthen comprehensive problem-solving abilities stimulate innovative research capabilities. For literacy objectives, we aim to cultivate scientific attitudes and craftsmanship spirit, shape team cooperation and communication ability, and enhance social responsibility and innovation awaremess[2].

2.2 Curriculum Content Design

With the purpose of applying what has been learned, the teaching mode of college physics experiment is reformed, and concepts and knowledge of innovation and entrepreneurship are integrated into the teaching process. Students are guided to actively participate in various physics experiment competitions. Meanwhile, a three-level module of "basic theory-comprehensive design-research innovation” is constructed. By integrating real problem situations, we consciously cultivate students’ abilities including independent learning, practical innovation, hands-on skills, learning planning skills, etc.

The basic theory module focuses on consolidating the experimental foundation and strengthening scientific thinking. The theory of measurement and error constitutes the main part of this module, which systematically teaches error analysis, uncertainty evaluation, significant figure processing, and common data processing methods such as the tabulation method, graphical method, successive difference method, etc. Through the measurement training of basic physical quantities, such as measuring diameter with a micrometer, length with a vernier caliper, and mass with a physical balance, students are trained to develop rigorous habits in experimental data recording. The new teaching syllabus covers 14 basic verification experiments, such as “Measuring solid density by the fluid weighing method”, “Measurement the speed of sound”, “Adjusting the spectrometer and measuring the apex angle of a prism”, etc[3]. These experiments enable students to be familiar with the operation specifications of common instruments such as oscilloscopes and spectrometers. Students can also understand the internal relationship between experimental principles and physical laws. At the same time, experimental safety education is indispensable. Integrating laboratory safety operation specifications and instrument maintenance knowledge, it cultivates students’ safety awareness and sense of responsibility.

In terms of teaching implementation, a blended pre-learning system is adopted. Relying on the campus network, a physics simulation experiment platform is built. Students learn instrument operations through online videos and simulate experimental processes through virtual simulation. Only after completing the pre-learning test can they enter the laboratory, realizing the flipped classroom mode of “learning before doing”. Heuristic teaching method is applied in the form of “question guidance + operation demonstration”. Teachers guide students to think deeply about experimental principles by setting questions such as “Why multiple measurements are needed?” and “What the main sources of error are?”. The assessment mechanism is mainly standardized, focusing on the standardization of experimental operation, the accuracy of data processing, and the completeness of experimental reports. Among them, the pre-learning part accounts for 20%, operation assessment 30%, and data processing & report writing 50%, so as to ensure that students fully master basic experimental skills.

The comprehensive design module focuses on combining with practical applications to cultivate students’ ability to solve practical problems. The experiments include “Determination of grating constant”, “Measurement of weak magnetic field by Hall effect”, “Measurement of Planck constant by photoelectric effect method”, etc. Students are required to apply their knowledge comprehensively, compare the advantages and disadvantages of different experimental methods, and develop knowledge transfer abilities. Open-design experiments are carried out with the given experimental objectives and constraints, such as “Measurement of micro-displacement”. Students independently consult literature, design experimental schemes, select instruments and equipment, and complete the experiment, while teachers only provide necessary guidance and resource support. In teaching implementation, project-based learning is adopted. Students complete comprehensive experimental projects in groups. Through the complete process of “problem proposal - scheme design - experiment implementation - result analysis - achievement report”, students’ team cooperation and problem-solving ability are cultivated. The evaluation system is diversified, combining process assessment and outcome assessment to comprehensively evaluate students’ comprehensive abilities[4].

The research and innovation module is committed to empowering innovation and entrepreneurship education and stimulating students’ potential in scientific exploration and original thinking. Various innovation and entrepreneurship practice projects encourage students to apply physics knowledge to solve practical social problems, such as “Light Wisdom: Vision-driven Optical Lighting System” and “Walking towards Light: Solar Intelligent Light-tracking System”, and so on. Students are supported to apply for national and provincial college students’ innovation and entrepreneurship training programs. In teaching implementation, a tutorial system is adopted for personalized cultivation. Each student group in this module is assigned two supervisors to provide “two-to-one” scientific research guidance, helping them formulate research plans, solve experimental problems, and cultivate the way of thinking in scientific research. Meanwhile, scientific research simulation training is carried out through the “Venus” College Student Science and Technology Innovation Project. By introducing research project management tools and academic writing norms, students experience the complete scientific research process, including literature retrieval, review writing, experimental scheme demonstration, project report, etc. Through “simulated scientific research project” training, students are helped to master the methods and skills of scientific research. Competition-driven teaching is implemented. Competitions such as the National College Physics Experiment Competition, National College Students' Energy Conservation and Emission Reduction Competition, "Internet +" Innovation and Entrepreneurship Competition are used as practical platforms. Corresponding training and guidance are offered to guide students to promote learning and innovation through competitions, thus improving their innovative and practical abilities. The evaluation adopts a result-oriented approach, mainly based on patent applications, competition awards, project reports, and other achievements. It focuses on the depth of thinking and practical contribution of students in the innovation process and encourages students to transform experimental results into practical applications.

2.3 Teaching Methods and Evaluation Mechanism

Under the guidance of the core concepts of "student-centered, problem-driven, practical innovation", a teaching method system of "layered adaptation, multi-element integration, dynamic adjustment" is constructed, which aims at the different objectives of the three-level modules of "basic theory, comprehensive design, research innovation" in college physics experiment courses. The system fully stimulates students' learning initiative and realize the transition from "passive acceptance" to "active exploration".

The basic theory module adopts a three-dimensional teaching method of "situational introduction + demonstration guidance + immediate feedback". Situational introduction is employed to introduce the experimental topics with real-life phenomena. For example, in the "grating" experiment, the problem situation of "Why can a cylindrical grating make things invisible?" is used to stimulate students' curiosity and thirst for knowledge. Demonstration guidance adopts the mode of "standardized operation demonstration + warning of error-prone points". It demonstrates key steps such as instrument calibration and data collection. It also reminds students of common problems in the Newton ring experiment such as "The instantaneous current is very large when the sodium lamp starts". This helps students quickly master standardized operating procedures. Immediate feedback relies on an intelligent experiment management system. After completing the experiment, students can upload their data to the reporting system, which automatically conducts error analysis and result evaluation, and gives scores. It also shows the difference between the results and actual values, thus realizing a closed-loop learning of "learning by doing, improving by learning".

The comprehensive design module uses a three-dimensional teaching method of "project-based learning + interdisciplinary collaboration + result orientation". Project-based learning transforms experimental tasks into specific projects, such as the "Electromagnetic Induction Energy Conversion Experiment Regulated by Arduino Program". Students work in groups to complete the whole process of "topic significance - scheme design - instrument purchase - experiment implementation and data measurement - result verification - project report". Teachers only provide guidance at key nodes, such as "How to select appropriate experimental instruments within the budget?", and encourage students to make independent decisions. The interdisciplinary collaboration method breaks professional barriers. Students from different majors are organized into groups to cultivate their team cooperation ability. The result-oriented method requires students to present experimental results in the form of experimental reports, physical models, academic posters, and so on, followed by conduct public defense. The works of groups with high comprehensive evaluation will be displayed and communicated at the university level.

The research and innovation module adopts a three-dimensional teaching method of "tutor personalized guidance + scientific research simulation training + competition driven". Students actively choose tutors, apply for undergraduate science and technology projects, and conduct research simulation training. They experience the complete research process and master research methods and skills, including literature retrieval and review writing, experimental scheme demonstration, scientific research achievement report, etc. The competition-driven method takes various levels of physics experiment competitions and innovation and entrepreneurship competitions as important carriers of innovative practice. Taking competitions as an opportunity, it promotes students to transform innovative ideas into practical achievements. For example, the project titled "Light Wisdom: Vision-driven Optical Lighting System" developed by our students won the first prize in the municipal Energy Conservation and Emission Reduction Competition, achieving a double breakthrough in innovative ability and practical results.

The whole module uses a support system of "online and offline blended teaching + virtual simulation assistance + process evaluation". Online and offline blended teaching utilizes online resources such as MOOC platforms and virtual simulation experiment platforms to realize a blended learning mode of “online preview + offline practical operation + online consolidation”. After students complete the learning of experimental principles and virtual simulation operations online, they then carry out real experimental operations in the laboratory. The process evaluation system establishes a “multi-dimensional, whole-process, diversified” evaluation mechanism. The evaluation content includes experimental preview, classroom participation, experimental operation skills, data processing ability, etc. The evaluation participants include teachers and students. The evaluation methods include classroom questions, experimental reports, group mutual evaluation, and achievement defense, so as to comprehensively and objectively evaluate students’ learning effects. For example, in the comprehensive design module, process-based evaluation accounts for 70%, including 10% for group cooperation performance, 30% for experimental scheme design, 20% for experimental operation process, 10% for achievement report, and 30% for summative evaluation (experimental report). It fully reflects students’ learning process and comprehensive abilities.

2.4 Analysis of Teaching Reform Effects

The ultimate effect of the teaching reform needs to be verified by multi-dimensional data support. This section comprehensively analyzes the actual effect of the teaching reform from three key dimensions: the improvement of students’ core abilities, the feedback of course satisfaction, and the achievements of discipline competitions, so as to provide a basis for subsequent teaching optimization. The statistical sample covers all the sophomore students of science and engineering in Grade 2024 in the university, with a valid samples of 989.

2.4.1 Comparative Data of Students’ Ability Improvement

The development of students’ core abilities is one of a key objective of the teaching reform. By comparing the evaluation data of students’ five ability dimensions before and after the reform (see Table 1), namely experimental operation, data processing, problem-solving, innovative thinking and team cooperation, we can clearly observe the promoting effect of the reform on students’ ability training.

Table 1: Statistical Table of Students’ Ability Scores.

Ability Dimension	Average Score before Reform	Average Score after Reform	Improvement Range
Basic Operation	71.2	82.3	11.1%
Data Processing	70.1	83.3	13.2%
Problem-solving Ability	67.4	88.8	21.4%
Innovative Thinking Development	60.3	75.7	15.4%
Team Cooperation Performance	65.6	80.9	15.3%

2.4.2 Course Satisfaction Survey Data

As direct participants in the teaching reform, students’ satisfaction with the course is an important indicator to measure the effect of the reform. This survey focuses on five core aspects: course content, teaching methods, evaluation system, experimental resources and overall experience, to comprehensively collect students’ feedback. The results of the course satisfaction survey show that the satisfaction rate of each item exceeds 85%, and the overall course experience satisfaction reaches 90.5%(see Table 2), indicating that the reform has been widely supported by students.

Table 2: Statistical Table of Students’ Satisfaction Survey Data.

Survey Item	Very Satisfied	Satisfied	General	Dissatisfied	Very Dissatisfied	Satisfaction (Top Two Items)
Course Content	52.2%	39.8%	7.6%	0.3%	0.1%	92.0%
Teaching Methods	48.6%	40.4%	9.3%	1.4%	0.3%	89.0%
Evaluation System	45.8%	39.6%	11.0%	3.2%	0.4%	85.4%
Experimental Resource Allocation	39.0%	49.8%	9.4%	1.5%	0.3%	88.8%
Overall Experience	50.1%	40.4%	9.0%	0.5%	0%	90.5%

2.4.3 Comparative Data of Discipline Competition Awards

Discipline competitions serve as important platforms for evaluating students’ comprehensive abilities and teaching quality. The growth of the number of awards can directly reflect the improvement effect of teaching reform on students’ practical application ability. The following is a comparison of students’ award data in relevant discipline competitions, such as physics experiment competitions and energy conservation and emission reduction competitions, for the two years before and after the reform(see Table 3).

Table 3: Statistical Table of Discipline Competition Awards.

Competition Level	Number of Awards before Reform	Number of Awards after Reform
Year	2022-2023	2024-2025
National	1	4
Provincial and Ministerial	6	10

After the reform, the number of awards won by students in discipline competitions has increased significantly, especially in national-level competitions. This fully demonstrates that the reform has enhanced students’ practical and innovative abilities, and also reflects the effect of the curriculum reform.

2.4.4 Existing Problems and Improvement Directions

Although the reform has achieved remarkable results, there are still some problems. For example, satisfaction with the rationality of the evaluation system is relatively low. Some students believe that the evaluation process still remains a certain degree of subjectivity. In terms of experimental resource allocation, the quantity of some cutting-edge experimental equipment is insufficient, failing to meet the needs of all students. In response to these problems, the evaluation system will be further optimized to enhance the objectivity and fairness of the evaluation. Investment in experimental resources will be increased, and cutting-edge experimental equipment will be updated and supplemented to provide students with better experimental conditions.

3. Conclusion

Against the background of “Classroom Revolution” and the construction of “New Engineering” and “New Science”, the reform and innovation of college physics experiment courses have become a key link in cultivating high-quality applied and innovative talents. This scheme takes “student-centered, problem-driven, practical innovation” as its core concept. By reconstructing the curriculum system, innovating teaching methods, and constructing a diversified evaluation system, it explores a physics experiment teaching path that meets the talent cultivation needs of the new era. Practical results show that the reform has effectively improved students’ experimental operation skills, comprehensive application ability and research innovation ability. It has also significantly enhanced students’ scientific thinking and innovative consciousness. This study provides a replicable practical paradigm for the teaching reform of college physics experiment courses, and has important theoretical and practical significance for promoting the “Classroom Revolution” and achieving the talent cultivation goals of “New Engineering” and “New Science”.

Acknowledgements

Research Achievements of the Teaching Reform Project at Beijing Union University, “Research on Application-Oriented Teaching Reform of College Physics Experiment under the Background of Classroom Revolution” (No. JJ2024Y052).

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