Preliminary Exploration of the Supply-Side Structural Reform for College Physics Experiment Course

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Abstract. The construction of Emerging Engineering Education (EEE) has imposed higher requirements on the development of college physics experiment course systems, while also providing more opportunities for curriculum reform. From the perspective of supply-side reform, the college physics experiment course represents the supply side, while the cultivation objectives of students from different disciplines and majors embody the demand side. To effectively address the contradictions between demand and supply, it is essential to continuously optimize resource allocation, stimulate the subjective initiative of teachers and students, and implement modular and hierarchical teaching methods. We have tapped into our potential and expanded our experimental program to 35 projects, an increase of 85%, without increasing the laboratory area or operational funds. Moreover, we have raised the number of permanent experiments from 20 to 25 per year without adding any extra class hours. Through a series of reform measures, we have achieved some remarkable results, as evidenced by the excellent performance of our students in the National College Student Physics Experiment Competition.

Keywords: College physics experiment; Supply-side structural reform

1. Introduction

To address the existing issues in China's economic development, the Central Committee of the Party has put forward the strategic policy of "supply-side structural reform." It emphasizes the need to make greater efforts in promoting economic structural reform while moderately expanding aggregate demand. The focus is on strengthening the supply-side structural reform, improving the quality and efficiency of the supply system, adapting it to changes in demand structure, and achieving a reasonable match between supply and demand, thereby enhancing the driving force for sustainable economic growth [1].

When looking at the development of higher education in China with the same perspective, prominent issues affecting talent cultivation include not only quantity but also structural problems. The main contradiction lies in the mismatch, inconsistency, and imbalance between supply and demand, primarily on the supply side rather than the demand side. In May 2015, the State Council issued the "Made in China 2025" plan, aiming to transform China from a manufacturing power to a manufacturing prowess and from "Made in China" to "Created in China." Against this backdrop, the Ministry of Education, together with relevant national ministries and universities, has formulated the "Fudan Consensus"[2], "Tianda Action" [3]and "Beijing Guidelines"[4] sounding the call for engineering education reform in universities to address the challenges of Industry 4.0 and implement the innovation-driven development strategy.

"College physics experiment" is a common foundational experiment course offered to various majors in science and engineering. It serves as the initial training for students in scientific experimental thinking, experimental methods, and experimental skills. It is the first step for students to engage in independent learning, cultivate innovative consciousness, and lay a solid foundation for subsequent courses and scientific research [5]. Research and exploration of the reform of the college physics experiment course system will contribute to the development and advancement of the Emerging Engineering Education [6-12].

2. Existing Problems

Different universities have continuously adjusted and improved their course systems based on their own characteristics, program offerings, training orientation, and educational objectives. They have established a set of interrelated and progressive course systems, from basic to advanced, from superficial to in-depth. The research and exploration of the reform of the college physics experiment course system has never ceased [13-15]. For example, there have been efforts to introduce virtual simulation experiments, blend online and offline learning, and reform assessment methods. However, the course systems of most universities still face several problems, mainly in the following five aspects:

a. Unclear training objectives for talent cultivation, lack of exploratory and design-oriented experiment projects that align with the overall goals and demands of cultivating innovative talents.

b. Outdated teaching models that fail to inspire students' initiative, remaining in a passive learning state.

c. Insufficient updates of experiment projects, disconnect from new technologies and methods, resulting in student disinterest.

d. Neglecting student differences and treating students from different levels and majors equally with a standardized system applied throughout the entire institution.

e. Unreasonable course evaluation system, where the phenomenon of "one exam determines lifelong outcome" or "one report determines lifelong outcome" still exists.

The aforementioned problems involve talent cultivation objectives, teaching content, teaching methods, and course evaluation. They require a comprehensive and systematic approach for resolution.

3. Solutions

3.1 Emphasize Differentiated Talent Cultivation Objectives. Some people compare schools to factories, where students are the materials to be processed and shaped according to the school's characteristics and talent cultivation objectives. Teachers are industrial workers in the assembly line. However, schools deal with living beings, which means individuals with unique characteristics. The fundamental task of schools is to cultivate individuals. This requires schools to not treat students as standardized products in pursuit of efficiency and productivity, thus neglecting and sacrificing their uniqueness, creativity, and initiative. Such teaching practices cannot yield high-quality educational outcomes or foster high-quality innovative talents.

Due to differences in levels of education and talent cultivation orientations among universities, the structural elements of the new engineering education system and the importance of individual elements may vary. Therefore, key to the construction of new engineering disciplines is to follow a path of connotative development. Firstly, it is necessary to reconstruct a reasonable structure among various elements to enhance the overall productivity of engineering education. Secondly, it is crucial to fully explore the educational resources spanned by different elements, tap their potential internally to improve quality, and expand externally to foster industry-university-research cooperation.

For the college physics experiment course, its teaching objectives should be based on the level of the institution and talent cultivation orientation. The focus should be on fully utilizing the teaching resources of the institution to enhance students' scientific literacy, develop their ability to discover and solve problems, and cultivate their practical innovation skills.

3.2 Emphasize Balanced Innovation in Teaching Content. The college physics experiment course is based on case studies. The teaching content, experimental methods, and the adjustment and usage of traditional instruments and equipment involved in classic physics experiments have an indispensable role in deepening students' understanding of physical laws, strengthening their knowledge of physics, and enhancing their scientific literacy. However, to meet the talent cultivation objectives of the new engineering disciplines, the teaching content of the college physics experiment course should not only focus on reinforcing classic experiments but also target the forefront of technology and the era. It should incorporate experimental content related to new energy, new materials, new technologies, artificial intelligence, and other emerging fields.

4. Implementation

4.1 Strengthening the Transition from High School to University [16]. With the reform and optimization of the college entrance examination policy, the requirements for physics as a subject for admission to science and engineering majors have gradually increased in universities. Most high schools across the country have strengthened the construction of physics laboratories, and teaching hardware and software have been significantly improved. However, there are still some high schools that, due to various reasons, have not established physics laboratories. Even in high schools with physics laboratories, the implementation of the training objectives for the physics experiment course at the high school level is often not ideal. Some students are not familiar with the use of vernier calipers, micrometers, oscilloscopes, and data interpretation criteria. Therefore, the college physics experiment course needs to undertake some "gap-filling" work. In response to this, we have introduced 15-hour optional courses in college physics experiment with an average annual audience of 150 students, accounting for about 5% of the new students majoring in science and engineering at our university. This action received widespread acclaim and achieved good results.

4.2 Unleashing Potential and "Specialization with Versatility". Each university has different conditions, enrollment scales, laboratory spaces, and so on. Therefore, it is crucial to develop corresponding experimental projects based on the school's hardware conditions, avoiding blindly following trends or comparisons. The concept of "specialization with versatility" entails the ability to tap into potential and introduce new technologies and methods, transforming traditional experimental projects into a series of progressively complex and interconnected experiments. We have implemented an "expansion and improvement" of the five existing experimental projects in our college physics experiment teaching center without increasing the laboratory area or operational funds. As a result, the number of experiments has increased from 20 to 35, with an expansion ratio of 85%. In the future, we will further conduct corresponding research work and strive to expand to about 50 experiments.

Taking the traditional pendulum experiment as an example, we can expand it into three to four experiments that gradually increase in difficulty and depth. At the same time, the cultivation objectives should evolve from mastering classical measurement techniques to understanding and mastering new technologies and methods. The progression of the pendulum experiment is shown in Table 1.

Table 1. Progression of the Pendulum Experiment

Number	Experimental Project	Cultivation Objectives
1	Measuring the acceleration due to gravity using a pendulum	Measurement of length and time
2	Constructing a statistical histogram and calculating uncertainty	Error theory and plotting statistical histograms
3	Investigating the relationship between the period of a pendulum and its angle of displacement	Handling systematic errors
4	Observing the motion of a pendulum using Tracker software	Application of new technology and data processing methods
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4.3 Modularization of Experimental Projects. Due to historical development and disciplinary positioning, each university has its own disciplinary strengths and program characteristics. Therefore, as a compulsory foundational course in science and engineering, the college physics experiment course should better serve the professional development and talent cultivation of the school using limited class hours.

Modularization of experimental projects entails integrating the strengths and characteristics of various disciplines and programs and rationalizing the allocation of teaching content based on their respective needs. This approach ensures the maximization of laboratory resource utilization while considering the cultivation objectives of different disciplines and programs. For example, our university classifies science and engineering majors into categories such as chemical engineering and materials, electromechanical and information, and pure science (including mathematics, chemistry, and biology). Based on this classification, different experimental projects are offered while ensuring necessary training. Table 2 illustrates examples of modularized experimental projects for different majors.

Table 2. Modularized Experimental Projects for Different Majors

Number	Major Category	Experimental Project
1	Chemical Engineering and Materials	Measurement of thin film thickness using elliptical polarization Photoelectric effect of liquid crystals Measurement of the Second Virial Coefficient
2	Electromechanical and Information	Transient processes of RLC circuits Study of chaos circuits Experiments on heat engines
3	Pure Science	Giant magnetoresistance effect Nuclear magnetic resonance Hydrogen atom spectroscopy

We have made reasonable arrangements for the student's semester schedule and the allocation of experimental devices and laboratories without increasing the class hours, which has increased the number of experiments offered by the university experiment center from 20 projects per year to 25 projects per year.

4.4 Hierarchical Experiment Content and Quality Evaluation. Based on learning patterns and differences in teaching objectives, the college physics experiment course is divided into different levels, including basic experiments, fundamental experiments, modern and comprehensive experiments, and design experiments, which is ranging from basic experiments to advanced experiments, from foundational training to skill enhancement, and from knowledge acquisition to knowledge application. This allows us to cater to the learning needs of students at different levels, including those with little to no prior knowledge, while also nurturing the innovative abilities of senior students. Since participating in the National College Student Physics Experiment Competition (teaching competition) for the first time in 2019, our teams have won a total of 3 first-prize awards, 6 second-prize awards, and 10 third-prize awards. Especially in the consecutive two sessions of the competition in 2021 and 2023, students from non-physics majors in our university defeated many competitors from schools with a strong advantage in physics majors, and both won first-prize awards.

In terms of evaluation, considering the diverse stakeholders, such as teachers, students, and departments, a multi-level evaluation mechanism is established. The evaluation includes classroom teaching, setting experimental objectives, and feedback from the departments. Classroom teaching evaluation mainly focuses on the assessment of students' performances during the experimental process. Setting experimental objectives primarily assesses students' achievement of the educational goals of the conducted experiments. The feedback from the departments mainly assesses whether the implemented experimental projects contribute to students' learning in subsequent specialized courses. The course evaluation is conducted on an annual basis. Based on the evaluation results, adjustments are made to the experimental projects and anticipated objectives to achieve better teaching outcomes.

5. Conclusion

Curriculum is the heart of higher education. It is the fundamental basis for talent cultivation and teaching work, as well as the key factor that influences and even determines the quality of education and teaching. The construction of new engineering disciplines has put forward higher requirements for the construction of college physics experimental course systems, but at the same time, it has also provided more opportunities for the reform of course systems. From the perspective of supply-side reform, college physics experimental courses represent the supply, while the cultivation goals of students in different disciplines and majors represent the demand. Only by continuously optimizing resource allocation, fully mobilizing the subjective initiative of teachers and students, and implementing modular and hierarchical teaching can we effectively solve the contradiction between the demand side and the supply side.

Deepening reform and addressing real problems are the only way to find effective solutions. Only by continuously strengthening the reform of the college physics experimental course system can we adapt to the development of the times, better meet the needs of the construction of new engineering disciplines, and truly fulfill the original mission of "strengthening the country through fostering talent in the field of education".

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