Innovation and Practice of Preparatory Physics Teaching Model Based on French Engineering Education System

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Abstract. Cultivating outstanding engineering talents has always been a hot issue that China's higher education has been focusing on solving. The thinking methods of physics play a crucial role in cultivating students' analytical and problem-solving abilities, however, most universities in our country adopt a traditional teaching method in physics courses, the passive learning in traditional teaching method lacks initiative and innovation, and cannot effectively cultivate high-quality innovative talents that contemporary society demands. In response to the demand for cultivating outstanding engineering talents in China and the current pain point problems in domestic university physics education, as a Sino-French cooperative institution, the Paris Curie Engineer School has drawn on the French engineer education system's preparatory physics education model. With a focus on "learning," the institution has practiced and explored the integration of teaching objectives, teaching resources, teaching methods, and teaching evaluation systems in preparatory physics courses. Compared to the traditional teaching method of college physics, the measures taken in our school could enhance students' learning initiative, deepen their understanding of physics knowledge, improve the effectiveness of physics course teaching, and provide reference for the innovation of normal college physics education.

Keywords: Preparatory physics; College physics; French engineering education; Teaching model innovation

1. Introduction

Cultivating outstanding engineering talents has always been a hot issue that China's higher education has been focusing on solving. In 2010, China launched the "Excellent Engineer Education and Training Program" [1], and subsequently proposed the implementation of "Excellent Program 2.0" [2] in the context of the construction of new engineering disciplines, demonstrating the urgent need of the country for cultivating outstanding engineering talents. French engineering education enjoys a high reputation internationally and has its own advantages and characteristics compared to engineering education in other countries. Preparatory education is an indispensable part of the French elite engineering education system, in the preparatory stage, the physics courses are more in-depth and extensive compared to those offered by domestic universities, and there are complementary experimental and tutorial courses to strengthen the consolidation and application of theoretical knowledge. Currently, many Chinese universities have collaborated with French engineering schools [3], introducing advanced French engineering education system and establishing Sino-French cooperative schools, including the Paris Curie Engineer School. However, the desired outcomes of French engineering education have not been achieved in China, mainly because Chinese students are accustomed to traditional passive learning, lacking initiative and enthusiasm in their studies, and having insufficient momentum in their learning after entering university [4]. To localize the concept of French engineering education and better serve China's higher education, it is necessary to improve student learning initiative in teaching concepts and teaching methods in order to establish a model for cultivating domestic outstanding engineering talents.

The Paris Curie Engineer School is the first Sino-foreign cooperative institution approved by the Ministry of Education (Approval No: MOE11FRA02DNR20171830N) at Beijing University of Chemical Technology (BUCT). The school is jointly established by BUCT and École Nationale Supérieure de Chimie de Paris (ENSCP), one of the finest chemical engineering schools in France, aiming to introduce the elite engineering education model from France, promote engineering education reform and the construction of the emerging engineering disciplines, and cultivate high-level innovative engineering talents [5].

The Paris Curie Engineer School adopts a two-stage training model, drawing on the French engineering education system. The first three years focus on basic education, emphasizing the development of students' solid knowledge in natural sciences (mathematics, physics, chemistry, computer science, etc.) and language skills (French, English). The following three and a half years focus on engineering education, emphasizing the cultivation of students' professional skills and engineering theories. In the preparatory stage, the physics teaching draws mainly from the curriculum of preparatory physics in the elite engineering education system specified by the French Ministry of Education [6], combining the needs of talent cultivation in China and the characteristics of Chinese students. Through continuous practice and innovation in the localization process, a distinctive physics teaching model has been formed, achieving certain results in cultivating students' solid foundation in physics theory and practical abilities. The teaching content of preparatory physics includes geometric optics, circuit, mechanics, thermodynamics, hydromechanics, electromagnetism, and wave physics, as shown in Fig. 1. Through the study of preparatory physics, students can comprehensively grasp the basic concepts, theories, and methods in physics, accurately describe the reasoning process of physical laws, and proficiently apply the learned physical laws to solve new physics problems [7], further to solve complex system engineering problems.

This article first points out the main problems in current college physics teaching. Then, four innovative measures are proposed to address these pain points problems, and the effectiveness of these innovative measures is analyzed. Finally, a summary of the work in this article is provided, and the shortcomings of current physics teaching are analyzed, with the hope of providing inspiration for the education of outstanding engineering talents in our country and the improvement of college physics teaching.

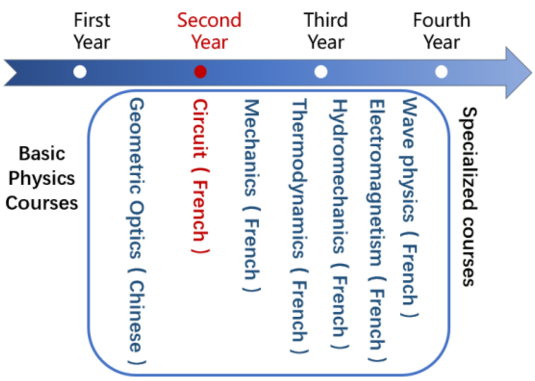

Figure 1. Physics courses content in Paris Curie Engineer School

2. Main Problems in Current College Physics Teaching

The thinking methods of physics play a crucial role in cultivating students' analytical and problem-solving abilities, improving their scientific literacy, stimulating their spirit of exploration and innovation. Most universities in our country adopt a traditional teaching method in physics courses, which is mainly teacher-centered. The characteristic of this method is that teachers directly present the content of textbooks or lesson plans to students through lectures. However, it has some issues such as single teaching method, biased evaluation, and low student participation in the classroom, which result in students being less active in learning, having low interest in studying, and having weak grasp of physics concepts, thus developing a habit of not actively thinking.

Obviously, the passive learning in traditional teaching method lacks initiative and innovation, and cannot effectively cultivate high-quality innovative talents that contemporary society demands. The current problems in college physics courses can be summarized as follows:

2.1 Inadequate Implementation of the Learning-centered Teaching Concept. The dominant teaching method in college physics courses is one-way knowledge transmission, which leads to students' lack of interest, lack of active thinking, lack of innovation, and the student-centered teaching model has not been truly established.

2.2 Difficulty in Integrating Theory and Practice in Depth. The combination of theoretical courses and experimental courses in university physics remains superficial and asynchronous, which makes it difficult for students to apply theory to practice and to deepen their understanding of theory through practice [8].

2.3 Outcome-Oriented Evaluation Methods are not Conducive to the Cultivation of Outstanding High-level Engineering Talents in the Context of the Development of New Engineering Disciplines. Currently, the evaluation methods for college physics courses are single and the evaluation system is imperfect, which is not conducive to the improvement of students' comprehensive abilities [9]. Moreover, this evaluation method cannot effectively track students' learning progress in the learning process.

3. Innovative Methods for Preparatory Physics in Paris Curie Engineer School

The preparatory physics course at the Paris Curie Engineer School has undergone more than six years of teaching practice. Through the integration of French and Chinese educational advantages, the joint efforts of the French and Chinese teaching teams, and the adherence to the educational philosophy of "student-centered, problem-oriented, and continuous improvement", innovative teaching methods have been integrated. Key construction has been carried out in terms of teaching objectives, teaching resources, teaching models, and evaluation systems, as shown in Fig. 2.

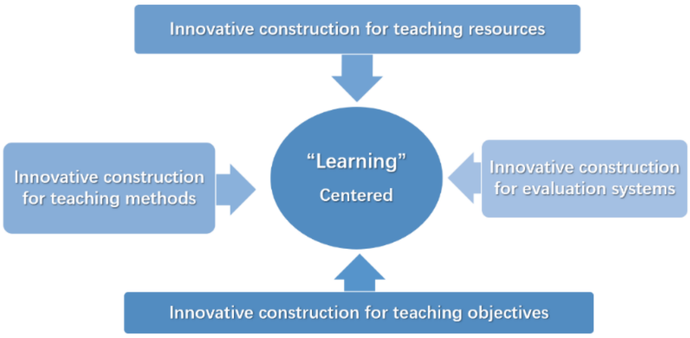

Figure 2. Innovative model of teaching objectives, teaching resources, teaching methods, and evaluation systems centered around "learning"

3.1 Innovative Construction of Teaching Objectives. The physics courses adhere to the education of ideology and politics, values guidance, and reconstruct the cultivation objectives in terms of knowledge, abilities, and character development. It aims to inspire students to have aspirations, to learn for the sake of responsibility and mission, and to realize their own value. By continuously updating the ideological and political case library and integrating it organically with professional content, ideological and political education is integrated into the teaching content. Through problem-oriented knowledge impartation and leading by example, ideological and political education is integrated throughout the learning process, achieving ideological and political education in the teaching process. By introducing the latest research achievements in the discipline, students' spirit of overcoming difficulties, critical thinking, and innovative qualities are cultivated, achieving ideological and political education in the discipline.

3.2 Innovative Construction of Teaching Resources. Comprehensively integrating diverse teaching resources and forming a unique "Five Combos" (combining domestic and international, online and offline, theory and practice, teachers and students, in-class and out-of-class) innovative resource supply model. Firstly, we recorded French teaching videos for all courses as well as Chinese videos explaining key and difficult points, while providing high-quality online teaching resources from both domestic and foreign sources. Additionally, the Chinese and French teachers have jointly built a database of course exercises and online test question banks for students to study outside of class, achieving the integration of domestic and international teaching resources as well as online and offline teaching resources. The content of theoretical classes and in-class experimental classes perfectly match and are conducted synchronously, achieving the integration of theory and practical resources. Furthermore, we have designed expanded experiments for students to complete autonomously in groups, and after completion, they showcase their experimental results to the whole class, achieving the integration of in-class and out-of-class resources. We encourage students to actively participate in course resource development based on projects, assisting in constructing learning plans that are more suitable for students, achieving the integration of teacher resources and student resources.

3.3 Innovative Construction of Teaching Methods. A C-TDP teaching mode is built, shown as Fig. 3, which combines large group theory classes (Cours), small group tutorial classes (Travaux Dirigés), and small group experimental classes (Travaux Pratiques). Adhering to the teaching philosophy of “student-centered, teacher-led”, adopting teaching methods mainly based on “team learning” and BOPSPPS teaching method, students’ conscious, active, cooperative, and exploratory learning mode is realized [10].

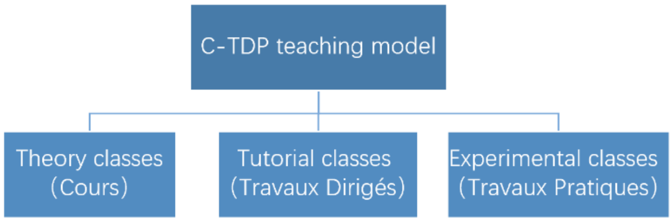

Figure 3. C-TDP teaching model

3.4 Innovative Construction of Evaluation Systems. In the theoretical part, a diversified evaluation system is designed, based on the learning data from the BUCT Online platform, as well as post-test data and in-class test data from Microsoft Forms questionnaires, as shown in Fig. 4. This strengthens data-based formative assessment and improves teaching strategies based on dynamic learning situations. In addition, in small class exercise classes, students are assessed on their logical and language expression abilities by showcasing and explaining their problem-solving processes. Individual oral examinations with the teacher are also conducted to assess students’ actual mastery of knowledge. For the experimental part of the course, a new and diversified evaluation system is established combining the evaluation of the experimental process, experimental reports, and experimental exams. During the experimental classes, the teacher observes students’ practical skills and assigns regular grades for their performance. The experimental reports mainly consist of open-ended questions, requiring students to analyze their experimental parameters and observed phenomena, effectively preventing plagiarism. Additionally, an experimental exam is added for the experimental part, with each student receiving different exam questions. Students raise their hands to indicate completion of key steps for the teacher’s inspection, who then asks operational or theoretical questions based on the experiment. A comparison of traditional evaluation method and the innovative diversified evaluation systems practiced in Paris Curie Engineer School for experimental part of physics is made in Table 1. This approach provides a more authentic and effective assessment of students’ mastery of the experimental part of the course, while also promoting students’ proactive improvement of their practical skills in regular experimental classes.

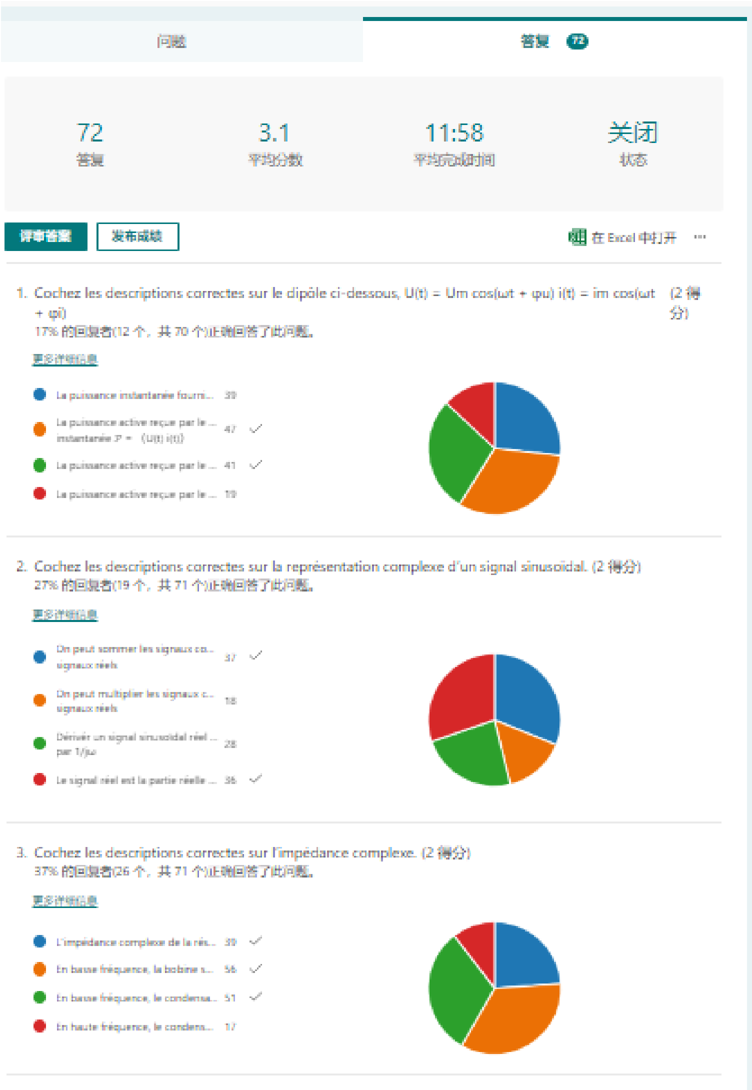

Figure 4. An example of test data from Microsoft Forms questionnaires

Table 1. Comparison of traditional evaluation method and the innovative evaluation systems practiced in Paris Curie Engineer School for experimental part of physics

Traditional evaluation method of experimental part for college physics	Innovative and diversified evaluation systems practiced in Paris Curie Engineer School for preparatory physics
Experiment report with relatively fixed format, single assessment form	During the experimental course, the teacher observes the students' hands-on operational abilities and gives them regular scores for their practical skills.
	The experimental reports mainly consist of open-ended questions, where students analyze their experimental parameters and observed phenomena, effectively avoiding plagiarism.
	A final experimental exam is introduced, where exam questions are randomly selected. Students are required to raise their hands to indicate completion of key steps for teacher inspection, followed by teacher questioning.

4. Conclusions and Perspectives

Through innovative practices in both theoretical and experimental aspects for preparatory physics, the new teaching system effectively cultivates students' desire for knowledge, ability to cope with challenges, and control over their learning process. It enhances students' "cognitive rehearsal" ability, allowing them to consolidate their acquired knowledge through sharing or teaching others. Additionally, it develops students' ability to summarize and report on multi-channel knowledge points, thereby improving their depth of understanding. The course also fosters students' scientific qualities of questioning and challenging difficulties, providing them with space for free innovation.

Currently, there are still areas where we can further improve and enhance the physics education effects in the following aspects: deepen the integration of information technology into teaching methods, strengthen the development of visualized resources for course theory, thus stimulating students' interest in learning and their desire for exploration, and further increasing student autonomy and the effectiveness of classroom teaching. Furthermore, we should promote the integration of teaching and research, and encourage interdisciplinary collaboration, closely coordinating with the mathematics and chemistry courses offered in our school, to form a more comprehensive and rational education program. With all these innovative measures taken in Paris Curie Engineer School for physics teaching, it is hoped to provide inspiration for the education of outstanding engineering talents in our country and the improvement of college physics teaching.

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