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The Course Reform of Mechanical Design Fundamentals to Cultivate Engineering Literacy and Innovation Ability

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Abstract: In view of the shortcomings of traditional teaching in the Mechanical Design Fundamentals course, the teaching resources are integrated, the teaching content, teaching methods, and assessment methods are reformed, scientific research results are introduced into course teaching, and the task-driven teaching practice is applied. These measures have improved classroom activity, stimulated independent learning, and laid the foundation for the cultivation of students' engineering literacy and innovative ability.

Keywords: Mechanical Design Fundamentals; Course reform; Task-driven

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1. Introduction

The Mechanical Design Fundamentals course integrates several contents, including "Mechanical Principle," "Machine Design," and other topics [1]. It is a fundamental course for engineering students. Since it contains rich theoretical knowledge and adheres to using knowledge to solve practical engineering problems, the course attempts to provide students a premise to understand and master engineering design by combining theory with practice.

The traditional teaching of mechanical courses is centered on knowledge transfer, which enables students to have a solid grasp of basic knowledge. These students, however, have a number of flaws, including limited knowledge, weak hands-on skills, poor engineering practice, and lack of innovative spirit and innovation ability, making it a challenge for them to grow as high-quality innovative talents.

The teaching team's priority is to find a way to reform the way Mechanical Design Fundamentals is taught so that students may learn the knowledge and skills needed for routine engineering work within a limited time, while also developing engineering literacy and innovation ability [2]. The teaching team of the Mechanical Design Fundamentals course in the National University of Defense Technology has made attempts to solve this issue.

2. Integrating teaching resources

In order to help students learn more effectively, the course team has classified and integrated various traditional teaching resources, such as books, courseware, lesson plans, teaching videos, and test questions, teaching models in accordance with the characteristics of mechanical disciplines, the types of teaching resources, the content of case materials, resource management models, and the internal relationships among resource service objects [3]. After thorough planning and design, a multi-dimensional integrated teaching resource platform is built [4], consisting of “physical object + model + video + multimedia courseware + online course,” as shown in **Figure 1**.

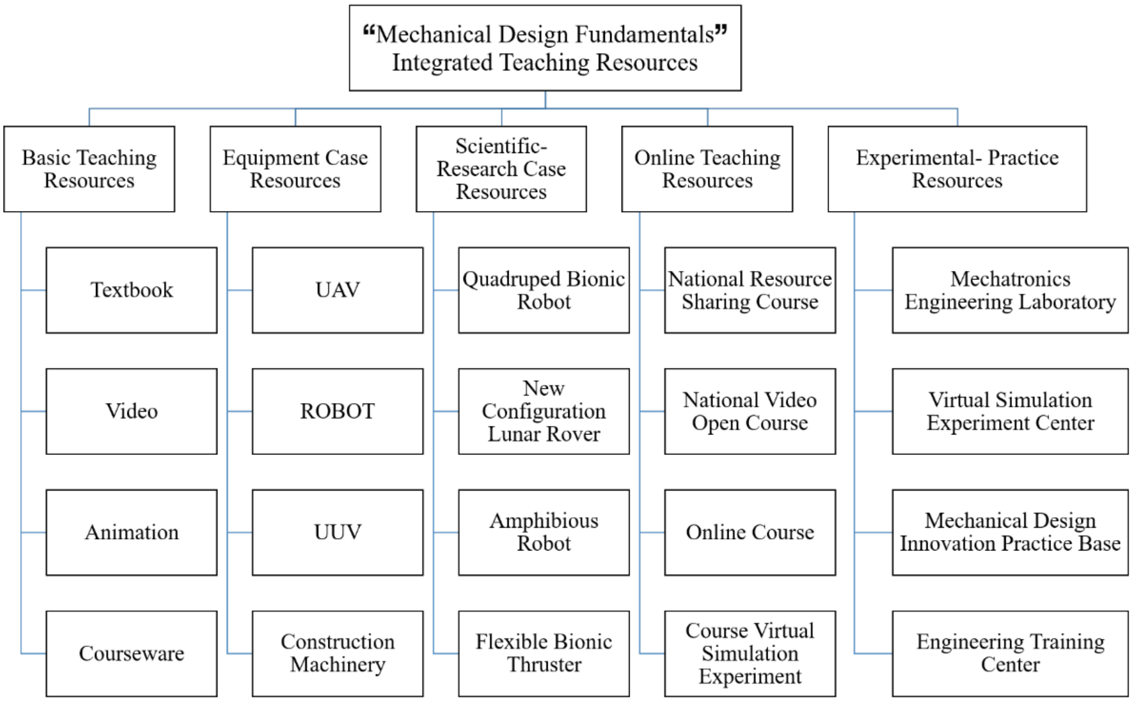

Figure 1. Integrated teaching resources of Mechanical Design Fundamentals

The demonstrations of physical objects and models improve students’ perceptual understanding of machinery; videos, on the other hand, deepen students’ understanding of the structure and principles underlying certain mechanisms and parts; computer animations enliven the classroom environment, while equipment and scientific research cases help students to understand the application of course knowledge and improve their engineering awareness; online teaching helps students to link in-class and after-class learning.

3. The reform of teaching content

In order to deal with the relationship between “less but refined” and “wide and new” in relation to the teaching content, the course team insists on focusing on the key points, difficulties, ideas, and methods of the teaching content; on the other hand, the team contends the timely introduction of the latest development of scientific frontier and engineering technologies into the classroom, so as to expand students’ knowledge and cultivate their innovative awareness and problem-solving skills.

Several measures have been taken for the reform of the teaching content.

(1) Carefully selecting the teaching content, and removing or replacing old and repetitive content

For example, in the design of linkage mechanism and cam mechanism, the analytical method is used instead of the traditional graphic method, which facilitates the comparison of transmission schemes, the selection of parameters, and the analysis of results. This is of no doubt conducive to the cultivation of students’ comprehensive ability. Another example, the tedious theory in gear transmission derivation is reduced, and its project practicality is highlighted.

(2) Embracing modern design methods that can improve students' problem-solving skills
    For example, when introducing the design of the linkage mechanism, optimal design methods, including the crank-rocker mechanism, the crank-slider mechanism, and the rocker mechanism, are introduced as examples, which not only solves the design problem, but also provides a set of optimal mechanism parameters.
(3) Introducing computer technology in the design process
    The boring design and check calculation process of mechanical parts is translated into MATLAB software program files. Students are then asked to read and modify the code in order to actualize their design process. This heightens students' interest and enhances their skills in using computers to solve practical engineering problems. For example, the design and drawing of cam profiles and the life calculation of rolling bearings are all written in M-codes based on the given topics. **Figure 2** is an example designed by a student.

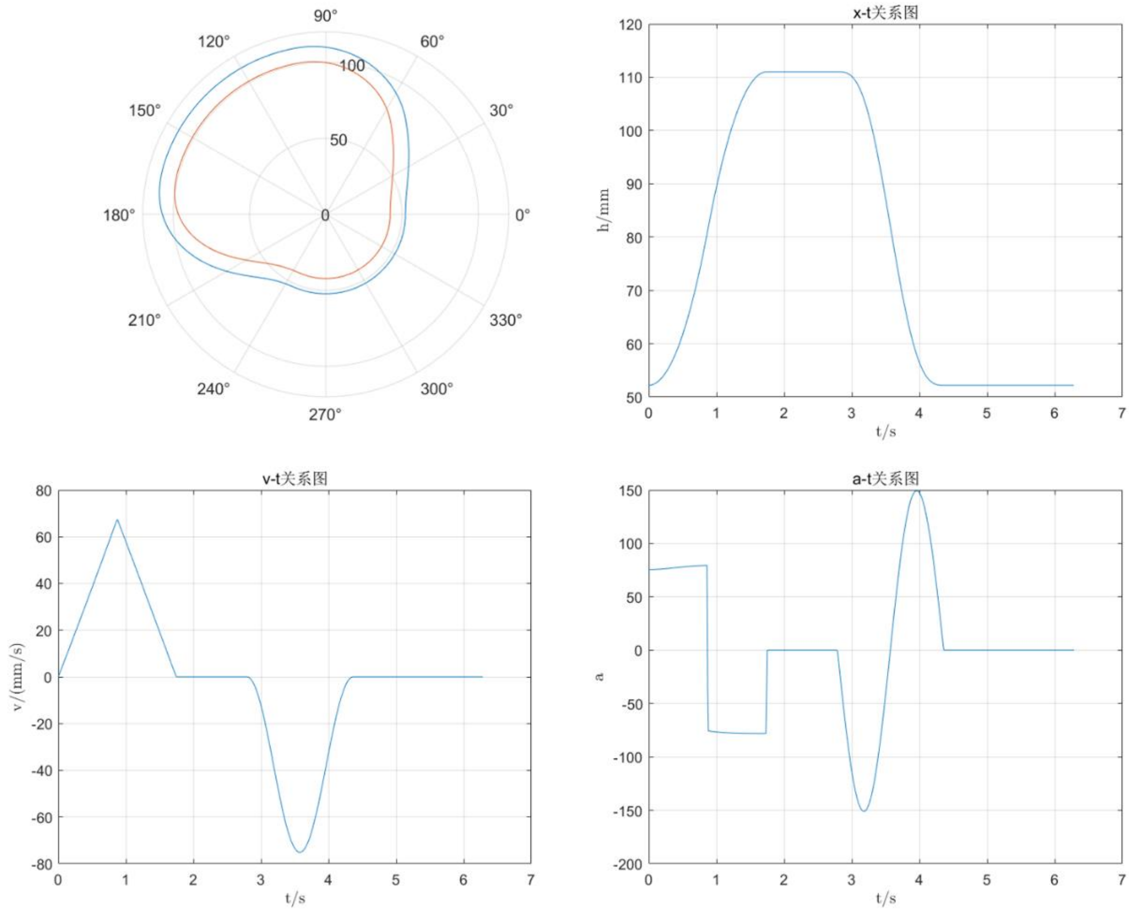

Figure 2. The design of a cam profile by a student

4. The reform of student-centered teaching methods

In order to improve the teaching quality of the Mechanical Design Fundamentals course, the course team attempted several teaching methods.

(1) Inspiration- and guidance-based teaching method
    The protagonist of the classroom has shifted from teachers to students. By posing questions to students concerning the course's knowledge points, they are encouraged to think actively, question boldly, discover and solve problems, understand thoroughly, as well as explore the important knowledge points and rules independently.

(2) Research- and inquiry-based teaching method

A discussion class has been set up to address the difficulties and key points of the teaching content. Through teachers' guidance, students can express their own views and question the opinions of others. Finally, teachers can then summarize and comment. This kind of participatory teaching enlivens the classroom environment and mobilizes students' enthusiasm for learning.

5. Introducing scientific research results into course teaching

Mechanical Design Fundamentals is a practical course, and machinery itself is closely related to the scientific research work of various majors. Transforming scientific research results into teaching resources and applying them in teaching not only promotes in-depth understanding of the knowledge points, but also improves students' engineering literacy and innovation ability. The course team has expended effort in this area.

(1) Some scientific research results are used as cases to be introduced into the teaching content. At same time, the cases are constantly enriched and refined, thus making the teaching content more attractive. For example, the achievements of the National Natural Science Foundation of China, the National Defense Pre-Research Projects, completed by the course team have been widely used in the course.

(2) In order to effectively cultivate students' practical skills, the course team has also developed new experimental equipment and designed a new comprehensive experimental project. This reflects the use of scientific research by the course team to enrich the course's experimental teaching, which strengthens the cultivation of students' innovation ability and practical skills. In recent years, several sets of experimental equipment have been developed, and several patents have been applied for.

6. Task-driven teaching practice

In order to help students attain purposeful learning, stimulate their creative desire, transform their learning from passive to active, and exercise their ability to solve practical engineering problems independently [5], the course team also attempted to apply the task-driven teaching practice in the course teaching, as shown in **Figure 3**.

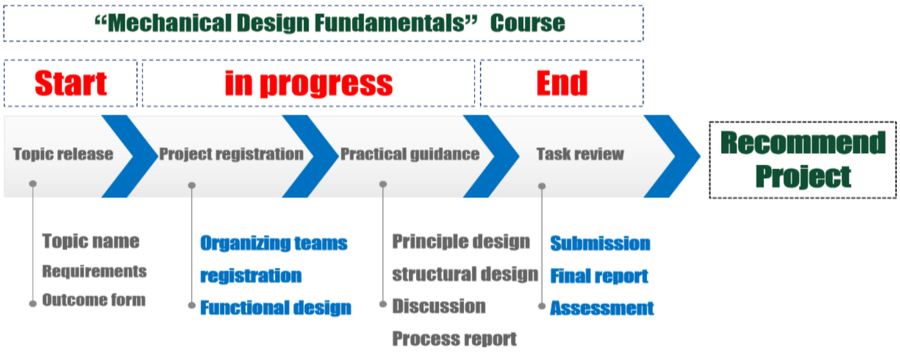

Figure 3. Task-driven teaching practice

At the beginning of the course teaching, a design task is arranged for the students. The topics are usually set by the teacher, but the students themselves are also given the option of selecting their own topics. During the course learning, students are required to complete the design task in groups in the form of extracurricular assignments and submit regular work reports. At the end of the semester, students are required to complete the project and submit the design results, which include the 3D models, motion animation, design manual, and courseware. The teacher will then grade their assignments based on the design results and their routine presentations.

Through such a method, the scattered knowledge points are connected, and students can gain familiarity and master basic theories and calculation methods, while developing a deeper comprehension of the course knowledge, in the attempt to apply their knowledge to engineering practice [6]. **Figure 4** shows some designed works by the students.

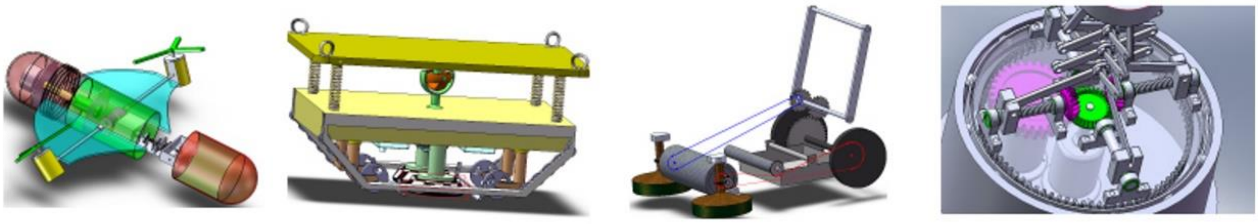

Figure 4. Designed works

7. The reform of assessment methods

In order to change the learning scenario of hardly revising before exams and improve students' self-consciousness and initiative for learning [7], the course team has also reformed the assessment method of the course.

The course team proposed a comprehensive assessment method, comprising of "diagnostic assessment + process assessment + final assessment," as shown in **Figure 5**. This assessment method changes the single-item timed and closed-book examination into a comprehensive assessment involving various domains, including daily homework, basic experiments, large-scale assignments, and final exam results. It reduces the proportion of scores from paper examination and focuses on the outcomes of the learning process (paper examination account for 50%, while the other domains account for the remaining 50%).

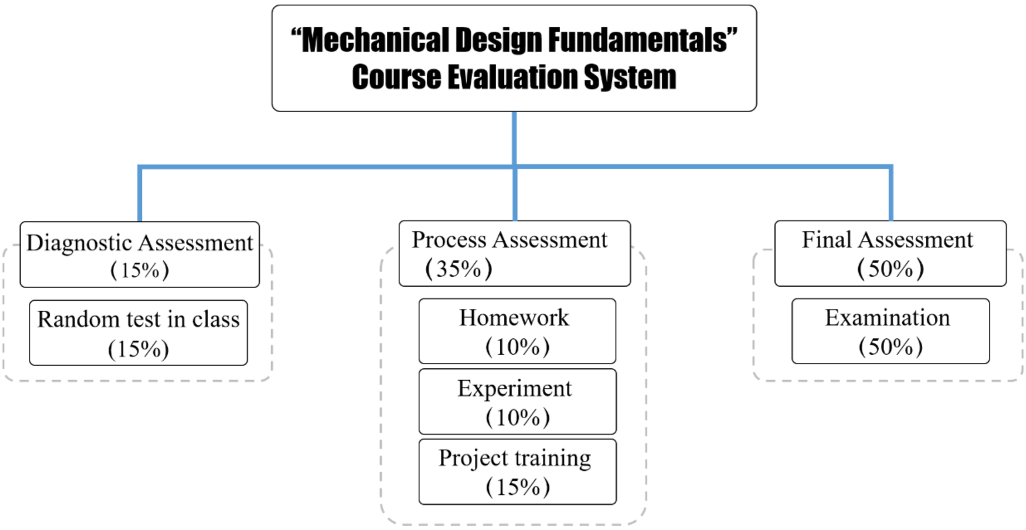

Figure 5. Course evaluation system

8. Conclusion

The reform of the Mechanical Design Fundamentals course has been well-received by students, and they are generally satisfied with the course. By increasing the students' engineering practice and innovation practice, they have won five provincial-level mechanical innovation design competitions within the past two years. The course team will continue to learn from advanced international and domestic teaching experiences and philosophies to further improve the instruction of Mechanical Design Fundamentals and cultivate more high-quality innovative talents.

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Disclosure statement

The authors declare no conflict of interest.

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