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Research on Teaching Reform and Evaluation Method of "Fundamentals of Mechanical Design" Course Based on Science-Education Integration

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Abstract: Aiming at the current issues of theory-practice disconnection and inadequate development of the innovation ability in the teaching of the "Fundamentals of Mechanical Design" course, this study proposes a reform and evaluation method of the course based on the science-education integration. By establishing a conversion mechanism of 'scientific research projects - teaching resources', the cutting-edge scientific research results of the discipline are transformed into modular teaching cases, forming a course content system that integrates theory and practice in depth. At the same time, a dual-track mechanism of 'process evaluation + outcome evaluation' is established based on the diversified evaluation system, and an evaluation system and evaluation criteria of the "Fundamentals of Mechanical Design" course are proposed.

1. Introduction

The in-depth promotion of new engineering disciplines and an innovation-driven development strategy means that higher engineering education is facing unprecedented opportunities and challenges. Currently, the global manufacturing industry is undergoing a critical period of digital and intelligent transformation [1], and the in-depth integration of the new-generation information technology and advanced manufacturing technology has put forward higher requirements for the cultivation of mechanical engineering talents. In this context, the science-education integration as an innovative educational concept is becoming increasingly important. This concept emphasizes the organic unity of the scientific research and teaching, using scientific research to update teaching content, improve teaching methods, and enhance teaching quality. It also focuses on collaborative learning among students and collaboration between teachers in scientific research and teaching [2,3]. Compared with the traditional education model, the science-education integration has significant advantages: not only can it transform the cutting-edge disciplinary knowledge and the latest scientific research results into high-quality teaching resources, but also effectively cultivate students' innovative thinking and ability to solve complex engineering problems [4]. Therefore, establishing a model of the science-education integration has become an important means by which the colleges and universities can cultivate new engineering talent and improve the quality of the talent development.

"Fundamentals of Mechanical Design", as an important cornerstone of the core curriculum system of the mechanical engineering, is a compulsory course in the second year for the near-mechanical majors at colleges and universities. The course aims to teach students the fundamental principles and design methods of general mechanical parts and structures, helping them to develop a comprehensive knowledge framework in mechanical engineering and lay a solid foundation for subsequent professional courses. And the course has a wide range of knowledge, strong theory, focus on application, rapid updating and other characteristics, its main objective is to understand the working principles and structures of mechanical mechanism, and have the comprehensive use of professional knowledge to complete the design of mechanical transmission devices, and have the ability to research and improve or develop new parts and components. Therefore, the "Fundamentals of Mechanical Design" course plays an irreplaceable role in developing students' mechanical design ability and engineering literacy. However, there are still many issues in the teaching of this course: Firstly, the teaching content is lagging behind, failing to reflect the development of cutting-edge technologies such as intelligent manufacturing and green design, and the textbook cases mostly remain at the level of traditional mechanical design; Secondly, the teaching mode is still based on theoretical indoctrination, with weak practical links and insufficient application of the modern teaching methods such as virtual simulation; Thirdly, there is a single way of assessment, which is overly focusing on the memory of knowledge and neglecting the cultivation of ability; Finally, there is a disconnect between the curriculum and research projects and a lack of opportunities for students to engage with real engineering problems [5] (see Figure 1 for the characteristics of the curriculum and the current teaching states). These issues have resulted in the phenomenon of ‘disconnection between learning and application’, and insufficient innovation consciousness and engineering practical ability among students. In this context, the key issues that need to be solved urgently are exploring the path of teaching reform through the deep integration of the science and education, and constructing a new teaching model that incorporates scientific research and project-based learning.

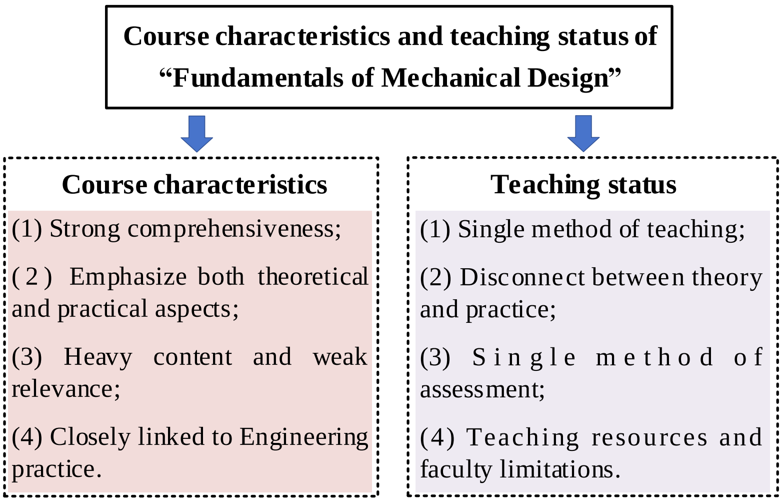

Figure 1: Course characteristics and teaching status of "Fundamentals of Mechanical Design".

In view of the above problems, this paper focuses on the core concept that scientific research feeds teaching and teaching promotes scientific research. It puts forward a teaching reform and evaluation method for the "Fundamentals of Mechanical Design" course based on the science-education integration. By reconstructing the course content system, innovating the teaching method, and optimizing the evaluation mechanism, the effective transformation of scientific research resources into teaching resources is achieved, and the engineering innovation ability and scientific research literacy of the students is enhanced. The main contents are structured as follows: the course teaching and learning reform is discussed based on the science-education integration in Section 2; The investigation of the course assessment method is introduced in Section 3; The main conclusions of this study are summarized in Section 4.

2. Design of the teaching reform based on the science-education integration

"Fundamentals of Mechanical Design", as a core course for near-mechanical majors such as robotics engineering and vehicle engineering majors, has distinctive disciplinary characteristics and teaching needs. The most notable feature of the course is the close integration of the theory and practice. In theory, students need to master basic knowledge such as mechanics and mechanical component design; In practice, it is necessary to cultivate practical hands-on abilities through CAD model, finite element simulation, experimental analysis, and other processes. Therefore, in order to meet these needs, the curriculum teaching needs to undergo various reforms.

2.1. Reconstruction of the teaching objectives of the course

The teaching objectives of the "Fundamentals of Mechanical Design" course need to break through the limitations of traditional knowledge transfer and construct a new objective system of ‘three-dimensional integration’. In the knowledge dimension, not only to consolidate the basic theories and design methods of the mechanical design, but also to integrate cutting-edge trends and the latest scientific researches in the discipline, so that students can master the classical theories and at the same time understand the development trend of the technology; In the ability dimension, the focus is on cultivating engineering practical ability, scientific research innovation ability, and complex problem-solving ability, and train students' design thinking and engineering literacy through participation in real research projects; In the quality dimension, the emphasis is placed on cultivating students' awareness of the engineering ethics, scientific spirit and lifelong learning ability, this will equip students with the comprehensive qualities needed to adapt to technological changes and industrial development. This reconstructed teaching objective not only maintains the foundation of the curriculum, but also strengthens the scientific research innovation, so that the cultivation of talents is more in line with the needs of the new engineering construction and industrial upgrading.

2.2. Reform of the teaching content of the course

In the reform of the teaching content of "Fundamentals of Mechanical Design" course, the focus is to establish a modular curriculum system of ‘foundation - frontier - practice’. In the foundation module, traditional teaching content is optimized and restructured by combining core knowledge points, such as mechanical principles and mechanical design, with typical scientific research cases; In the frontier module, the latest achievements of the faculty research team in the fields of the digital design and intelligent operation and maintenance are introduced, and the topic of ‘Frontier of Mechanical Innovative Design’ is set up; In the practical module, relying on scientific research laboratory equipment to develop step-by-step experimental projects, including basic experiments (such as mechanism motion analysis), comprehensive experiments (such as ANSYS-based structural optimization) and innovative experiments (such as robotic mechanism design), and transforming subject competition topics such as the ‘Student Mechanical Innovation Design Competition’ into curriculum design projects. At the same time, the updated dynamically scientific research case library will be established, with 3–5 teachers' vertical/horizontal projects selected for transformation into teaching cases each year. This will ensure that the teaching content is updated in line with technological development and that scientific research resources are effectively transformed into teaching resources.

2.3. Innovation of the teaching methods of the course

A complete teaching adopts a three-dimensional linkage teaching mode of "online offline practice" to reconstruct the teaching process, and establishes a multi-dimensional innovative teaching system with the core concepts of scientific research feedback the teaching and practice deepening the theory. The online stage relies on the MOOC platform to build a digital resource library that includes micro-courses on scientific research cases, virtual simulation experiments and cutting-edge developments in academia, guiding students to explore independently; The offline stage adopts seminar-type and project-type teaching methods to transform scientific research results into teaching cases and strengthen critical thinking training; The practical stage relies on teachers' scientific research projects and disciplinary competitions to promote students' participation in real scientific research projects and realize the integration of ‘learning, research and innovation’. This model effectively enhances students' innovation ability and scientific research quality through the teaching of scientific research resources, the practice of teaching process, and the innovation of practice process, forming a virtuous cycle of ‘knowledge construction-capability enhancement-scientific research application’.

3. Curriculum assessment methods under the science-education integration

3.1. Construction of a diversified assessment system

The aim of constructing a diversified assessment system is to overcome the limitations of traditional single-exam assessment and establish a more comprehensive, scientific and dynamic assessment mechanism. The system adopts a dual-track mechanism of ‘process assessment and outcome assessment’: The process assessment focuses on the cultivation of students' thinking and is monitored dynamically through dimensions such as online learning, classroom discussion, post-course assignment and project design; The outcome-based assessment focuses on the verification of students' ability, incorporates the final exam and project report into the scope of assessment, and introduces a multi-subject assessment method that combines students' self-assessment, mutual assessment and teachers' assessment. This method pays attention to both learning outcomes and the learning process, thus achieving a scientific assessment of the teaching effect of the "Fundamentals of Mechanical Design" course and an objective reflection of the students' comprehensive abilities. This multivariate assessment system not only focuses on the level of the knowledge mastery, but also emphasizes the comprehensive development of the scientific research literacy, innovation ability and practice level, which provides accurate quality feedback for cultivating talents based on the science-education integration. The components and proportions of the course assessment are shown in Table 1, including online learning, classroom discussion, post-course assignment, project design, final exam, and project report, with corresponding weights of 10%, 10%, 10%, 10%, 30%, and 30%, respectively.

3.2. Development of assessment and evaluation criteria

According to the assessment and evaluation methodology for the "Fundamentals of Mechanical Design" course presented in section 3.1, the assessment components include online learning, classroom discussion, post-course assignment, project design, final exam and a project report. Each component is rated by percentage, and the evaluation criteria for each component are as follows:

(1) Online learning: Students should take the initiative by watching teaching videos, participating in research case studies and completing innovative practical tasks, and carry out independent exploration in conjunction with online resources.

Table 1: Course assessment components and proportions

Assessment components			
Process evaluation		Final evaluation	
Contents	Proportions	Contents	Proportions
Online learning	10 %	Final exam	30 %
Classroom discussion	10 %		
Post-course assignment	10 %	Project report	30 %
Project design	10 %		

(2) Classroom discussion: Students should listen carefully to the lectures, understand the course content, and take the initiative to participate in group discussions with scientific research cases, using theoretical knowledge to analyze practical engineering problems.

(3) Post-course assignment: Students are expected to complete a comprehensive task including theoretical calculations, innovative design and submit the results on time.

(4) Project design: Students should work in teams to complete the entire process, from analyzing requirements and designing schemes to verifying simulations, and submit comprehensive results containing technical reports and 3D models.

(5) Final exam: Students should complete the knowledge assessment of the theoretical foundation within the specified time.

(6) Project Report: Students should complete a comprehensive research report on the project topic, containing the literature review, innovative design, simulation/experimental verification and engineering application analysis.

4. Conclusion

This study is based on the concept of the science-education integrating, and systematically constructs a reform framework for "teaching research evaluation" in the "Fundamentals of Mechanical Design" course. By establishing a mechanism for transforming scientific research projects into teaching cases, a modular teaching resource library in cutting-edge fields is developed, and solving effectively the problem of lagging teaching content; The innovative adoption of the project-driven teaching methods is improved significantly students' engineering practice ability; The diversified evaluation system is constructed to achieve a comprehensive and dynamic assessment of the knowledge, ability and quality.

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