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Teaching Reform of Theoretical Mechanics under the Guidance of Emerging Engineering Education

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Abstract: "Theoretical Mechanics" is a core course for engineering majors and plays an important role in promoting the development of science, technology and society. This paper explores the teaching reform methods of the Theoretical Mechanics course under the guidance of Emerging Engineering Disciplines construction. First, it sorts out the current teaching content, teaching status and prominent problems of the course, and expounds the important significance of teaching under the guidance of Emerging Engineering Disciplines construction in stimulating students' interest and cultivating their abilities, which is specifically reflected in three aspects: clarifying the training orientation for solving complex engineering problems, promoting the update and modular reconstruction of curriculum content, and improving students' engineering literacy, innovation awareness and employability. In addition, it elaborates in detail the implementation paths for Emerging Engineering Disciplines construction to improve teaching quality, including reconstructing the teaching system, strengthening practical teaching, and deepening industry-university integration, so as to comprehensively promote the synchronous development of the "Theoretical Mechanics" course and Emerging Engineering Disciplines, and enhance the effectiveness and pertinence of teaching. Finally, it is pointed out that the in-depth integration of Emerging Engineering Disciplines construction and the teaching of Theoretical Mechanics can effectively improve teaching quality and cultivate high-quality engineering talents who meet the needs of the new era.

1. Introduction

In recent years, the construction of Emerging Engineering Education (3E) has been continuously advanced, with its core educational philosophy fully and thoroughly implemented in various higher engineering colleges and universities. The core objective of 3E is to cultivate high-quality outstanding engineering talents with innovative, entrepreneurial and interdisciplinary capabilities, enabling them to adapt to the iterative changes inin future industrial development and address new challenges brought about by industrial restructuring and technological upgrading.

Theoretical Mechanics, a core basic course studying the fundamental laws governing thegoverning objects’ mechanical motion, is based on classical mechanics, revealing the internal correlation between force and motion and providing essential theoretical support for fields such as modern engineering analysis, equipment design and and system dynamic simulationcore . As a technical course for engineering majors, it is vital for cultivating students’ rigorous logical reasoning, scientific engineering analysis analysis thinking andability to solve complex practical engineering problems.

At present, the teaching of Theoretical Mechanics still relies heavily on traditional classroom lecturing, and students mainly acquire knowledge in a passive way [1]. Characterized by abstract theories, complicated formula derivation and insufficient connection with engineering practice, this course often results in students’ low learning enthusiasm and weak initiative, thereby hindering the cultivation of innovative thinking. Such a situation fails to meet the development demands of emerging engineering education. Accordingly, it is of important theoretical significance and practical value to effectively integrate innovative thinking training into Theoretical Mechanics teaching.

In previous studies, T. V. Makarova et al. [2] focused on research skill training for engineering undergraduates. They highlighted the inadequate cultivation of preliminary independent research abilities in early engineering education, and verified the unique advantages of Theoretical Mechanics in this regard as a basic science course, proving its indispensable role in emerging engineering education.

Chundong Wu et al. [3] summarized three prominent problems in current teaching: disconnected curriculum content from engineering practice, low student attention, and passive cramming teaching. Correspondingly, they proposed four reform measures: optimizing teaching content and methods, building engineering case libraries, promoting interdisciplinary study, and implementing diversified evaluation systems.

Tingting Liu [4] explored learning difficulties and reform strategies of Theoretical Mechanics. She concluded four major learning constraints, including vague learning goals, biased prior concepts, cognitive obstacles and weak mathematical foundations. Targeted strategies were put forward to clarify learning objectives, eliminate thinking barriers, regulate cognitive behaviors and strengthen mathematical competence, so as to improve students’ academic performance and comprehensive learning ability.

As a core fundamental course for engineering majors, Theoretical Mechanics features rigorous logic, high abstraction and distinct engineering applicability. It plays an irreplaceable role in consolidating students’ theoretical foundation and cultivating their scientific thinking and modeling ability. Transforming cutting-edge research achievements into high-quality teaching resources and feeding classroom teaching with research paradigms can enrich teaching connotation, and effectively stimulate students’ learning initiative, innovative awareness and practical competence.

From the perspective of emerging engineering education, this paper explores and practices the teaching reform of Theoretical Mechanics. It aims to solve major teaching bottlenecks such as low learning interest, difficult theoretical comprehension and weak knowledge application, and provide valuable reference and practical support for deepening curriculum reform and improving the overall quality of talent cultivation.

2. The Current Teaching Situation and Problems of "Theoretical Mechanics"

2.1. Teaching Contents

The current teaching materials of Theoretical Mechanics adopt a traditional content system with outdated knowledge and insufficient integration of emerging engineering elements such as numerical calculation and mechanical simulation, which is increasingly disconnected from engineering practice. In the chapter of planar motion of rigid bodies, for instance, textbooks mainly adopt ideal models such as sliders and levers for theoretical derivation, while lacking dynamic modeling cases of real engineering structures including robotic arms and vehicle suspensions. Most examples and exercises are overly idealized with poor comprehensiveness and engineering relevance. This will make it difficult to effectively cultivate students ' ability of mechanical modeling and complex engineering problem solving, and cannot fully meet the needs of engineering education in the new era.

2.2. Present Situation and Prominent Problems in Teaching

Traditional Theoretical Mechanics teaching has five key deficiencies. First, the course orientation is inconsistent with the goal of talent training, and insufficient attention is paid to the cultivation of mechanical thinking and engineering practice ability. Second, the teaching content emphasizes too much on theoretical deduction, lacks full integration with engineering practice and professional requirements, and the knowledge system is updated slowly. Third, the teaching mode is relatively single, and the classroom interaction is insufficient, which inhibits the initiative of students ' learning and increases the difficulty of understanding abstract concepts. Besides, the practical teaching link is relatively weak, too much emphasis on problem solving training and neglect the cultivation of modeling ability, lack of comprehensive and innovative practical projects. Finally, the evaluation method is too single, mainly based on summative evaluation, which cannot fully reflect the development of students ' learning process and comprehensive ability.

Liu Yizhi et al. [5] noted students’ insufficient cognition to distinguish Theoretical Mechanics from college physics mechanics. Rais Mingalievich Timerbaev et al. [6] found only 13% of students could conduct systematic independent learning, due to poor self-learning readiness and long-cycle independent assignments, making teaching optimization urgent.

3. Significance of Emerging Engineering Education for the Teaching Reform of Theoretical Mechanics

3.1. Clarifying the Competence Training Orientation for Complex Engineering Problems

As a national strategy, Emerging Engineering Education focuses on cultivating high-quality engineering talents capable of solving complex engineering problems. As a core fundamental course for engineering majors, Theoretical Mechanics directly affects students’ mechanical literacy and engineering capabilities. Under the guidance of Emerging Engineering Education, clarifying the course’s orientation of cultivating competence for complex engineering problems serves as the core guide for its teaching reform.

Emerging Engineering Education promotes the transformation of curriculum objectives from "knowledge transmission" to "competence orientation", breaking the traditional limitation of "valuing theory over application" and focusing on students’ core capabilities such as engineering modeling and mechanical analysis. It also clarifies the advanced requirements of the course, guiding students to master the abilities of model abstraction, system analysis, comprehensive solution and simulation verification, so as to enhance the course’s advanced nature and challenge.

In addition, it aligns with engineering education professional certification, cultivates students’ closed-loop ability to solve engineering problems, and realizes the transformation from "being able to solve exercises" to "being able to solve engineering problems". It also leads the upgrading of curriculum objectives, strengthens students’ logical and engineering thinking, and provides top-level guidance for the reform of curriculum content, teaching modes and evaluation systems. In summary, Emerging Engineering Education clarifies the competence training orientation of

Theoretical Mechanics, promotes curriculum transformation, and supports the cultivation of engineering talents and the high-quality development of basic mechanics courses.

3.2. Promoting Curriculum Content Update, Case-Based and Modular Reconstruction

Guided by industrial demands and cutting-edge technologies, the Emerging Engineering Education provides direction for curriculum content reform. Its core role is reflected in three dimensions, solving the problems of outdated traditional curriculum content and disconnection from engineering practice.

First, the reform needs to promote the iterative updating of content and connect the frontier with the industrial demand. Focusing on fields such as intelligent manufacturing and aerospace, emerging engineering drives the course to delete pure theoretical derivations divorced from engineering, integrate the application of mechanics in emerging fields, and supplement relevant knowledge such as modern simulation, so as to realize the synchronization of content with industry and technology.

Second, the reform needs to promote the case-based content, strengthen the connection between theory and engineering, introduce real engineering cases, combine the principles of abstract mechanics with practice, and break the dilemma of emphasizing theory and neglecting application in the past mechanics courses.

Third, the reform needs to promote modular reconstruction and disassemble modules according to the core competence of mechanics. At the same time, it also needs to adapt to interdisciplinary and personalized training, take into account the needs of different majors, and improve the pertinence and practicability of the course.

3.3. Improving Students' Engineering Literacy, Innovation Awareness and Employability

With engineering orientation and innovation cultivation as its core, the new engineering construction improves students' comprehensive abilities through the teaching reform of Theoretical Mechanics from three key dimensions, laying a solid foundation for their career development.

First, reform needs to improve students ' engineering literacy. Promoted by emerging engineering, the course is connected with engineering practice, guiding students to establish engineering thinking, master the application methods of mechanical principles in practical scenarios, cultivate their rigorous engineering attitude and basic literacy in solving practical problems, and get rid of the limitations of pure theoretical learning. Second, reform needs to strengthen students ' innovative consciousness. Through the teaching reform of case analysis and comprehensive design, students are inspired to think actively, which can guide them to use mechanical knowledge to optimize engineering schemes, solve complex problems, and cultivate innovative thinking and source innovation ability. Third, reform to enhance employment competitiveness. The curriculum reform is aligned with industrial needs, enabling students to possess the capabilities of mechanical application and simulation analysis required by enterprises, adapt to the job requirements of fields such as intelligent manufacturing and aerospace, and improve their core employment advantages.

4. Paths for Improving Theoretical Mechanics Teaching Quality under 3E

Under the guidance of emerging engineering construction, the overall implementation path for the teaching reform of "Theoretical Mechanics" is shown in Figure 1, and the specific methods of the teaching reform under the new engineering orientation are elaborated in detail below.

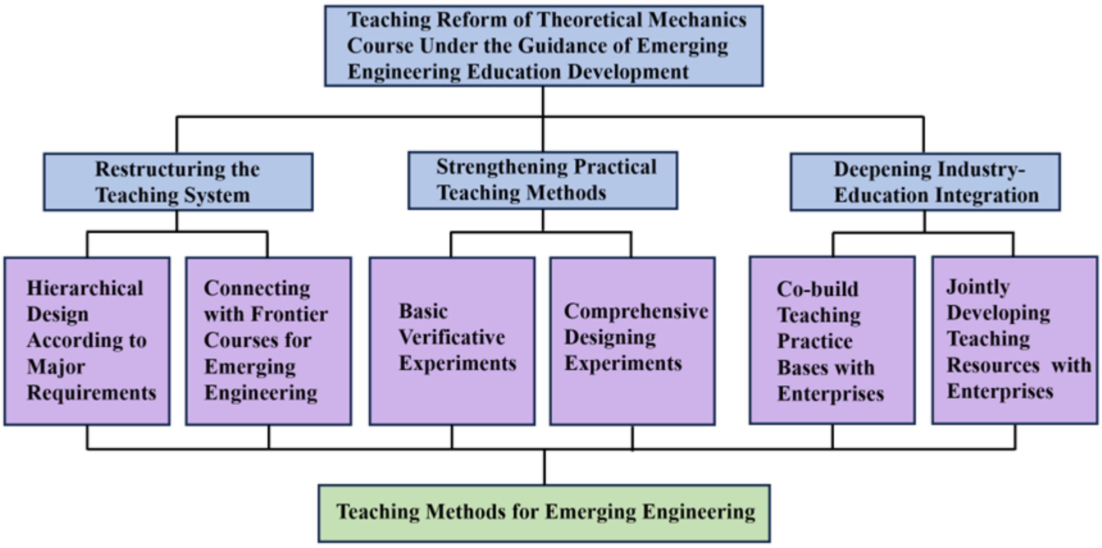

Figure 1: Overall Path Map of Theoretical Mechanics Teaching Reform under Emerging Engineering.

4.1. Reconstructing the Teaching System

To reconstruct the teaching system, it is necessary to anchor the new engineering competence goals and build a "hierarchical progression and interdisciplinary integration" curriculum system.

The construction of new engineering requires basic course teaching to serve the talent training needs of different engineering majors and connect with cutting-edge engineering technologies. It is necessary to break the traditional "one-size-fits-all" teaching system of "Theoretical Mechanics" and set up courses separately according to different disciplines.

4.1.1. Design by Major Requirements in Layers

Set up teaching content divided into basic layer, professional layer and expansion layer according to the engineering application scenarios of different engineering majors such as mechanical engineering, civil engineering, aerospace engineering and vehicle engineering. The basic layer is a compulsory course for all majors, covering the core theories of statics, kinematics and dynamics, so as to lay a solid foundation for mechanical modeling and analysis. The professional layer customizes course content according to professional characteristics — for example, the mechanical major focuses on planar motion of rigid bodies and mechanism dynamics, while the civil engineering major focuses on statics equilibrium and structural force analysis. The expansion layer introduces interdisciplinary content, such as multi-body dynamics combined with robot engineering, and coupled analysis of fluid mechanics and theoretical mechanics combined with new energy engineering.

4.1.2. Connecting with Frontier Courses of Emerging Engineering

Establish a connection channel between "Theoretical Mechanics" and subsequent professional core courses as well as cutting-edge elective courses. For example, the reform can combine theoretical mechanics knowledge with courses such as "Robot Technology," "Intelligent Equipment Design" and "New Energy Structure Design," and set up cross-curriculum comprehensive projects, so that students can experience the application value of theoretical mechanics in the field of new engineering.

Meanwhile, integrate engineering literacy such as engineering standards, engineering ethics, team collaboration and problem-solving into all links of teaching. From the course introduction to practical assignments, real engineering problems are taken as the guide to help students establish the thinking of "solving practical engineering problems with mechanical theories".

4.2. Strengthening Practical Teaching

Centering on engineering orientation, a three-level practical system is built via basic experiments, engineering design and school-enterprise practice. Practical teaching is essential for emerging engineering construction and high-quality Theoretical Mechanics instruction. Traditional practical teaching relies on monotonous verification experiments. The new engineering reform breaks this limitation, realizing the transition from theoretical verification to engineering design and real engineering practice.

4.2.1. Basic Verification Experiments

The classical theoretical mechanics verification experiments (such as statics balance experiment, rigid body fixed axis rotation experiment, collision experiment, etc.) are retained, but the experimental methods are innovated. So that students can design experimental schemes independently, operate experimental equipment by themselves instead of bystander experimental teachers, follow up the experimental data and analyze the experimental error, so as to cultivate students' experimental operation and data processing ability, rather than simple onlooker experimental process or mechanical step-by-step operation.

4.2.2. Comprehensive Design-oriented Experiments

The reform can set up comprehensive design experimental projects, such as "Comprehensive Experiment on Kinematics and Dynamics of Multi-Rigid-Body Systems" and "Force Design and Verification Experiment of Simple Engineering Structures". Students are allowed to combine theoretical knowledge to independently complete experimental scheme design, mechanical model construction, experimental equipment debugging and experimental result analysis after the experiment, so as to cultivate their comprehensive ability to integrate theoretical knowledge with experimental operation.

Meanwhile, the university can cooperate with enterprises in the fields of intelligent manufacturing, aerospace, new energy, civil construction, etc., establish an off-campus practice teaching base, organize students to carry out on-site practice in enterprises, and let students observe the application of theoretical mechanics in the design, production and research and development of practical engineering products. Besides, the university can invite enterprise engineers into the classroom, carry out engineering practice lectures, guide students ' curriculum design and project learning, and let students understand the actual engineering needs of enterprises.

4.3. Deepening Industry-Education Integration

The core of emerging engineering construction is industry-education integration and science-education integration. To improve the teaching quality of Theoretical Mechanics, it is necessary to closely align with industrial development needs, break the barriers between universities and enterprises, and realize in-depth coordination of teaching, scientific research and industry.

4.3.1. Establishing Teaching Practice Bases in Cooperation with Enterprises

When cooperating with leading enterprises in intelligent manufacturing, aerospace, new energy, civil engineering and other fields, in addition to establishing off-campus practical teaching bases, it is also necessary to jointly build theoretical mechanics teaching bases and digital training centers. Enterprises provide universities with practical equipment, engineering cases and project resources, while universities cultivate engineering talents that meet the needs of enterprises, so as to realize the sharing of resources between universities and enterprises.

4.3.2. School-Enterprise Joint Development of Teaching Resources

The joint development of teaching resources by universities and enterprises mainly involves cooperating with enterprise engineers to develop teaching materials, handouts, engineering case libraries, practical training projects, etc. It integrates the actual engineering needs and technical standards of enterprises into teaching resources, making the teaching content more in line with the actual industrial development, cultivating students in a targeted manner to better meet enterprise needs and facilitating their employment after graduation.

Meanwhile, the scientific research achievements of university teachers in the fields of theoretical mechanics and engineering mechanics, as well as the engineering R&D achievements cooperating with enterprises, are transformed into teaching content and introduced into classroom teaching and practical links. This enables students to access the latest scientific research achievements and engineering technologies, and cultivates their scientific research thinking and engineering innovation capabilities.

In response to the specific talent needs of enterprises, customized theoretical mechanics teaching modules are carried out. For example, the "multi-body dynamics" teaching module is customized for robot enterprises, and the "structural force analysis" teaching module is customized for new energy enterprises, so as to achieve precise alignment between talent training and industrial needs. It can also enrich the course content and arouse students' interest in classes.

5. Conclusions

The construction of new engineering disciplines points out the direction for the teaching reform of "Theoretical Mechanics", requiring alignment with engineering practice and competence development. The reform addresses the shortcomings of traditional teaching, such as poor professional adaptability and disconnection between theory and practice, by focusing on three core aspects: reconstructing the teaching system, strengthening practical teaching, and deepening industry-university integration.

Hierarchical teaching content tailored to professional needs enhances targeting and forward-looking, laying a solid foundation for students. Practical teaching combining basic verification and comprehensive design cultivates students’ abilities in modeling, operation and application. The industry-university integration model, through university-enterprise cooperation and joint resource development, breaks down barriers between teaching and industry, aligning teaching with real engineering needs.

In the future, continuous optimization of hierarchical teaching content, enrichment of practical projects and deepening of university-enterprise cooperation will further improve teaching quality, laying a solid foundation for cultivating compound engineering talents with theoretical foundation, practical ability and innovation.

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