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Reform of the Teaching Mode for "Mechanics of Materials" Course Driven by Academic Research

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Abstract: "Mechanics of Materials" is a core course in engineering disciplines and is becoming increasingly significant for the development technology and society. This article discusses how academic research can assist in the teaching of "Mechanics of Materials", analyzing the existing problems in the current teaching of "Mechanics of Materials", and elaborating the significance of integrating academic research into teaching in stimulating students' interest and cultivating their abilities. In addition, the ways are elaborated in detail, in which academic research can support teaching, including integrating research findings into teaching content, conducting practical teaching based on research projects, guiding theoretical teaching with research thinking, and improving teachers' teaching abilities through research activities. Finally, it is pointed out that the deep integration of academic research and the teaching of "Mechanics of Materials" can effectively improve teaching quality and cultivate high-quality engineering talents who are adaptable to the needs of the new era.

1. Introduction

In recent years, the new engineering education concept has been deeply implemented in engineering colleges and universities. The aim of new engineering education is to cultivate outstanding engineering talents with innovative and entrepreneurial capabilities and high-quality interdisciplinary and comprehensive skills, to adapt to the development changes of future industries and be able to cope with new challenges brought about by industrial transformation and technological reform. "Mechanics of Materials" is a course that studies the deformation laws of objects. Based on the principles of mechanics, it investigates the mechanical properties of materials and explores their relationships with structure and preparation of the materials, etc. It holds significant strategic importance for optimizing material performance and developing intelligent materials. It is a core technical foundation course for engineering majors and is extremely helpful in enhancing students' ability to solve practical engineering problems. With the rapid development of technologies such as big data, artificial intelligence and cloud computing, digital intelligence empowerment has brought new opportunities for the new engineering discipline education,

especially for the development of the subject "Mechanics of Materials". However, currently, the teaching of "Mechanics of Materials" is mainly based on lecture-style teaching, with students being in a passive state of accepting knowledge, which leads to a lack of learning interest and motivation among students for this subject, and is not conducive to the cultivation of students' innovative thinking. Therefore, how to effectively cultivate students' innovative thinking in the teaching of "Mechanics of Materials" has extremely important research significance.

In the previous reports, Wang et al.[1] expounded how to teach mechanics courses in a way that takes into account the psychological characteristics and ideological status of the "05" generation of college students. The "05" generation of college students born after the year of 2005 represent the latest generation of students. They have remarkable differences from the previous generations of students in terms of their growth environment, learning experiences, and social cognition. Therefore, targeted approaches are necessary in course establishment. Li et al.[2] discussed the effective ways of integrating online and offline elements to conduct the course "Mechanics of Materials". Jiao et al.[3] in response to the three major pain points commonly in traditional teaching methods, i.e., numerous knowledge points, outdated engineering cases, and difficulties in practical application, proposed the teaching concept of "teaching according to individual differences" and "striving for innovation". However, there has been few reports regarding how academic research contribute to the development of the "Mechanics of Materials" discipline.

Research is a combination of innovation and forward-looking perspective, and it is the fruit of innovative thinking. Academic achievements have increasingly significant impacts on the comprehensive capabilities and development of universities. Transforming research results into teaching resources and enriching teaching content with academic achievements is one of the effective ways to cultivate students' interest in learning and innovative thinking. This article discusses the exploration and practice for the teaching model of "Material Mechanics" driven by academic research, breaking through the constraints such as low learning interest, weak innovative thinking, and poor practical ability, and step forward for the goals of educational reform and the comprehensive improvement of students' qualities.

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

2.1 Teaching Contents

The contents of the textbooks are relatively outdated. Many classic textbooks focus on traditional materials and conventional mechanical problems, and have relatively little coverage of the mechanical properties of new materials (such as nanomaterials, intelligent materials, etc.) and related mechanical issues. This makes it difficult to reflect the latest development trends of the discipline. The teaching contents are not closely linked to practical engineering applications, and students often feel that the theoretical knowledge is abstract and do not know how to apply the knowledge they have learned to practical engineering. As a result, students' ability to solve practical engineering problems is insufficient. For example, when explaining the bending deformation of beams, only simple rectangular beams are used for theoretical calculations, while there is relatively little explanation of beams with complex shapes in actual engineering and the force analysis under various working conditions.

2.2 Teaching Methods

The traditional teaching method, which mainly relies on teachers' lectures, still dominates the current teaching models. In the classroom, teachers focus on imparting knowledge, but fail to adequately stimulate students' initiative and creativity in learning. Students are in a passive state of

accepting knowledge during the learning process, lacking the active thinking and independent exploration, which is not beneficial for cultivating students' innovative thinking and autonomous learning abilities. Moreover, In the experimental teaching section, most experiments are just for verification, where students follow the steps in the experimental guidebook to operate, lacking in-depth understanding of the experimental principles and independent design of the experimental process, making it difficult to establish students' practical and innovative abilities. For example, in the material tensile experiment, students merely mechanically record data, lacking in-depth analysis of the material mechanical performance changes reflected by the experimental data. Habib Sadid once proposed to revise the themes in material mechanics so that the basic equations and combined loads could be introduced at the beginning of the semester. Then, more in-depth discussions would be conducted on the analysis and design of more complex structures, mechanical components, and systems under combined loads[4].

2.3 Learning Interest and Ability Development of Students

Due to the limitations of the teaching content and methods, students perform little interest in the "Mechanics of Materials" course and consider it boring. In terms of ability cultivation, students' engineering practical skills, innovation ability, and the ability to solve complex problems are not effectively exercised and improved. This leads to students often feeling at a loss when facing complex mechanical problems in real engineering situations, and they have difficulty in quickly adapting to the job after graduation.

3. The Significance of Academic Research in Enhancing the Teaching of "Mechanics of Materials"

3.1 Stimulating Students' Learning Interest

The cutting-edge issues and innovative achievements in academic research often show tremendous appeal. Incorporating research results into the teaching of "Mechanics of Materials", such as the application of new materials in the aerospace field, mechanical problems in micro-electromechanical systems, etc., can enable students to understand the extensive and significant practical applications of mechanics of materials and make the abstract mechanical knowledge more vivid and interesting. This will stimulate students' interest in learning and their desire for exploration. When students learn how scientists use the knowledge of mechanics of materials to solve key problems in actual engineering, they will develop a strong interest in the course and actively learn and explore related knowledge.

3.2 Cultivating Students' Innovative Thinking and Practical Abilities

Engaging in scientific research activities or conducting practical teaching based on scientific research projects enables students to experience the process of scientific research firsthand, and learn the thinking patterns and research methods of scientists. During the process of solving scientific research problems, students need to apply the knowledge of material mechanics for analysis and thinking, and propose innovative solutions. This helps to cultivate students' innovative thinking abilities. Through practical operations and experiments, students can enhance their practical hands-on skills, integrating theoretical knowledge with practical application, and improving their ability to solve practical problems. For instance, having students participate in the research project on the optimization design of composite material structures, they need to conduct mechanical analyses of different structural forms using material mechanics knowledge, and verify

the feasibility of the optimization solutions through experiments. In this process, students' innovative thinking and practical abilities can be effectively exercised.

3.3 Improving the Cutting-Edge Nature and Practicality of the Teaching Content

Academic research activities can continuously promote the development of disciplines and generate new technologies. When teachers incorporate their research achievements or the latest research developments into the teaching content, it enables the teaching content to keep up with the times and be at the forefront. Simultaneously, research projects often originate from actual needs of engineering and introducing actual cases from research projects into teaching can enhance the practicality of the teaching content, allowing students to better understand the mechanical problems in actual engineering and their solutions, and improving their ability to apply knowledge. For example, when teachers introduce their research results on the structural design of battery packs for new energy vehicles into the teaching, the explanation of how to use material mechanics knowledge to optimize the structure of the battery pack to improve its safety and reliability enable students to acquire knowledge that is more closely related to practical engineering applications.

4. The Approaches for Enhancing the Ability of Teaching "Mechanics of Materials" via Academic Research

The overall path map for the teaching approach of "Mechanics of Materials" assisted by academic research is shown in Figure 1. The following text will elaborate on how academic research contributes to the teaching of "Mechanics of Materials".

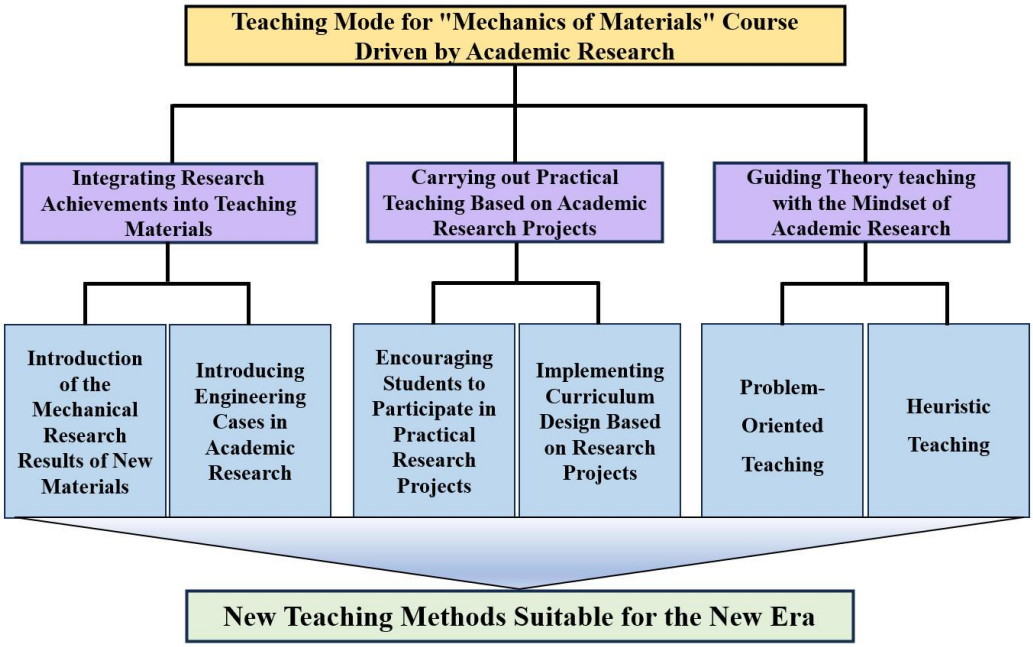

Figure 1. Overall path map for the teaching approach of "Mechanics of Materials" course assisted by academic research.

4.1 Integrating Research Achievements into Teaching Materials

4.1.1 Introduction of the Mechanical Research Results of New Materials

The advancement of technology stimulates the emerging of new types of materials constantly,

including graphene, shape memory alloys, and metamaterials etc. These new materials possess unique mechanical properties, and their research results have brought new opportunities for the field of material mechanics. During the teaching process, teachers can introduce the mechanical research results of these new materials at the appropriate time, explaining their mechanical performance characteristics, research methods, and application prospects in practical engineering. When explaining the elastic modulus of materials, one can compare the differences in elastic modulus between traditional materials and new materials, and introduce that graphene has an extremely high elastic modulus, making it have great application potential in aerospace, electronic devices, and other fields. Through such explanations, students not only can learn the cutting-edge knowledge of the discipline, but also can recognize the importance of material mechanics knowledge in the research of new materials, and stimulate their interest in researching new material mechanics problems.

4.1.2 Introducing Engineering Cases in Academic Research

A large number of practical engineering cases are included in academic research projects, which are highly representative and practical [5]. Teachers can select some academic research engineering cases related to teaching content to introduce into course teaching, combining abstract mechanics knowledge with practical engineering problems, to help students better understand and apply knowledge. When explaining the stability of compression bars, a case of the stability of bridge piers under compression in bridge engineering can be introduced, describing how to use the knowledge of mechanics of materials to analyse and design the stability of bridge piers, as well as what measures are taken in actual engineering to improve the stability of bridge piers. Thus, students can understand the concept and principle of the stability of compression members more intuitively and master the methods and ideas for solving practical engineering problems.

4.2 Carrying out Practical Teaching Based on Academic Research Projects

4.2.1 Encouraging Students to Participate in Practical Research Projects

Colleges can organize students to participate in the teachers' research projects, to develop their practical and innovative abilities in an actual research environment[6]. Teachers can assign research tasks related to the "Mechanics of Materials" course to students based on their knowledge levels and abilities, such as collecting and analysing experimental data, establishing and solving mechanical models, etc. During the research project practice, teachers should provide students with sufficient guidance and support, guiding them to apply the knowledge they have learned to solve practical problems. Students participate in the research project on the mechanical properties of composite materials, responsible for the preparation of composite material specimens, mechanical performance testing, and the analysis and processing of experimental data. Through participating in this project, students can not only master the operational skills of material mechanics experiments proficiently, but also deeply understand the mechanical properties characteristics of composite materials and their influencing factors, and improve their practical ability and problem-solving skills.

4.2.2 Implementing Curriculum Design Based on Research Projects

Course design is an important practice part in the teaching of "Mechanics of Materials". The traditional course design topics are often rather simple and lack innovation and comprehensiveness. Teachers can combine their own research projects to give course design topics based on the research projects, allowing students to apply the knowledge of mechanics of materials in the course

design and solve practical research problems. During the course design, students need to consult a large amount of literature, understand the relevant research background and current research status, and then carry out work such as establishing mechanical models, calculating parameters, and designing schemes according to the given requirements of the research project. For example, with the course design topic of "Optimization Design of a Certain Aircraft Wing Structure Based on Mechanics of Materials", students need to use the knowledge of mechanics of materials to analyse the force of the wing structure, to establish a mechanical model, and then to optimize the design of the wing structure through optimization algorithms to improve the performance and reliability of the wing. Through such course design, students can comprehensively apply the knowledge they have learned, and cultivate their innovation ability and the ability to solve complex problems.

4.3 Guiding Theory Teaching with the Mindset of Academic Research

4.3.1 Problem-Oriented Teaching

During the theory teaching process, teachers can draw on the problem-oriented thinking used in research, starting from practical problems and guiding students to think and explore. Teachers can pose some practical engineering problems or research issues related to the teaching content, asking students to consider how to apply the knowledge of material mechanics to solve these problems. When explaining stress and strain analysis, teachers can raise questions of "In the structural design of high-rise buildings, how can the stress and strain distribution in different parts be accurately analysed to ensure the safety of the structure?" to prompt students to think about the methods and steps of stress and strain analysis. Through this problem-oriented teaching approach, it can stimulate students' interest in learning, cultivating their problem awareness and problem-solving abilities, and also enabling students to realize that the process of academic research is constantly raising questions and solving problems.

4.3.2 Heuristic Teaching

Continuous thinking and exploration are necessary in the research process. Heuristic teaching can guide students to think like researchers. In the teaching process, teachers can set some stimulating questions, encouraging students to have discussions, and encourage them to express their own opinions, thereby inspiring students' thinking. When explaining the bending theory of beams, teachers can firstly raise some questions about the phenomenon of beam bending, such as "Why does there exist a stress difference between the upper and lower surfaces of the beam when it is bent?", "How can the cross-sectional shape of the beam be changed to improve its bending resistance?" Let students think and discuss with others, and then gradually guide them to deeply understand the bending theory of beams. Through this heuristic teaching, students' autonomous learning ability and innovative thinking ability can be cultivated, enabling them to gradually master the methods and thinking patterns of scientific research during the learning process.

5. Conclusions

As a crucial driving force for the development of disciplines, academic research plays an indispensable role in the teaching of the "Mechanics of Materials" course. By integrating research achievements into the teaching materials, conducting practical teaching based on research projects, guiding theoretical teaching with research thinking, and enhancing teachers' teaching skills through research activities, the current problems in the teaching of "Mechanics of Materials" are expected to be addressed effectively, stimulating students' interest in learning, cultivating their innovative thinking and practical abilities, improving the cutting-edge and practical nature of the teaching

content, and promoting the joint improvement of teachers' teaching and academic research levels. From the implementation of cases, academic research has significant potential in contributing to the teaching of "Mechanics of Materials", and students can made notable progress in knowledge acquisition, ability cultivation, and overall quality improvement. Therefore, in the future teaching of "Mechanics of Materials", we should further strengthen the deep integration of academic research and teaching, continuously explore and innovate teaching models and methods to meet the needs of cultivating high-quality engineering talents in the new era, and provide more outstanding professionals for the engineering construction and technological development.

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