Research on Teaching Reform and Practice of Mechanics of Materials Course Based on Engineering Application

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Abstract: In light of the mounting societal demand for innovative and applied engineering talents, the significance of the mechanics of materials course in higher education is escalating. Consequently, there is an urgent necessity to make substantial adjustments to the course's teaching method and content, with a view to optimising them. The conventional educational model has proven ineffective in aligning with the contemporary demands of society for talent development, necessitating an urgent reform. The integration of advanced materials science and innovation knowledge, the implementation of project-based teaching methodologies, and the establishment of a diversified assessment system have the potential to facilitate more effective enhancement of students' practical abilities and innovative thinking. The fundamental objective of this series of reform measures is to enhance students' ability to apply in real engineering projects, to promote a closer match between engineering education in universities and the needs of the industry, and to lay a solid foundation for the cultivation of high-quality talents to meet the challenges of the future.

Keywords: Mechanics of Materials; Engineering Applications; Teaching Reform; Discipline Development

1. Introduction

The Mechanics of Materials course is a compulsory component of the engineering curriculum, encompassing a diverse array of subjects including mechanical foundation, material properties, and structural analysis. This course is of paramount importance in the field of engineering, as it provides a foundation for understanding various engineering applications. However, as engineering practice has evolved, conventional teaching methods have proven ineffective in meeting the demand for talent in contemporary engineering technology. In order to facilitate the personalised development of students and the cultivation of independent learning abilities, there is an urgent need for in-depth thinking and improvement. At present, there are relatively few research results and practical experiences on the construction of "mechanics of materials" course, which is still in the preliminary exploration stage. There is a lack of diversity in the integration of cases in the course, and the contents and forms are relatively uniform, especially in the cultivation of students' sense of social responsibility and professional ethics through a variety of actual engineering cases. In addition, the integration of cutting-edge knowledge into the teaching process is also insufficient, which fails to effectively stimulate students' creativity and makes it difficult for students to fully realise the importance and interest of the course. Therefore, it is necessary to improve the theoretical system and implementation path of "Mechanics of Materials" course construction, so as to provide solid support for the cultivation of engineering talents with all-round development of morality, intelligence and physical fitness. In order to enhance the quality of education and cultivate talents with practical engineering skills, many universities have proposed a new classroom model of "learning-centered and teaching-led" in the reform of curriculum teaching. In this paradigm, students are not merely recipients of knowledge, but also the primary agents of learning. Teachers function as facilitators, organisers and coordinators, optimising classroom teaching design, increasing interactivity and applying a variety of teaching methods to enhance students' learning. Consequently, the effective implementation of this pedagogical approach in the domain of mechanics of materials has emerged as a pivotal subject in educational and teaching research [1].

2. Problems in the Traditional Mechanics of Materials Classroom

The initiation of teaching reform must be predicated on a comprehensive acknowledgement of the prevailing issues within the teaching process. It is only through such a comprehensive recognition that we can undertake a thorough analysis, leading to the identification of effective solutions. These solutions, in turn, must ensure that the reform aligns more closely with the demand-oriented goals. A review of the relevant literature was undertaken, and personal experience in teaching practice was combined, in order to identify the following major problems in the current classroom teaching of mechanics of materials.

2.1 Disconnect between Theory and Practice

Mechanics of materials is a typical applied discipline. It involves a large number of theoretical derivations and calculations, as well as the application of theoretical knowledge to specific engineering practices. Nonetheless, the conventional materials classroom places excessive emphasis on theoretical explanations, thereby overlooking the implementation of engineering applications. This pedagogical approach often hinders students' ability to seamlessly integrate theoretical knowledge with practical problems, impeding effective problem-solving and application-oriented learning. In the conventional classroom setting, the instructor primarily focuses on the derivation of formulae and subsequently provides guidance to students, aiming to facilitate their mastery of the fundamental principles of mechanics and mathematical models. However, a significant proportion of students during the learning process encounter difficulties in comprehending the practical applications of theoretical knowledge in engineering contexts. For instance, although students learn the stress-strain relationship of materials in the classroom, they may not be clear about how these relationships are applied to actual engineering design, material selection and structural analysis. Despite the theoretical mastery of formulae demonstrated by students in written exercises, they frequently encounter challenges in applying these concepts with the requisite flexibility in practical engineering problems [2].

2.2 Teaching Methods are Too Homogenous

The conventional pedagogy employed in materials science classrooms is predominantly a didactic approach, wherein the instructor delivers a lecture to the students. Whilst the lecture-centred teaching method is capable of delivering fundamental knowledge, it has been observed that students may experience a lack of engagement and interactivity, which can result in a diminution of their enthusiasm. Firstly, it is evident that educators typically utilise the board and PowerPoint presentations to methodically develop key concepts, while students passively receive the knowledge presented. While this pedagogical approach can elucidate the principles of mechanics in a more systematic manner, it is challenging to stimulate students' interest in the subject. It has been demonstrated that, in the case of abstract knowledge points, a simple explanation is often perceived by students to be uninteresting or tedious. Secondly, the conventional classroom rarely employs group discussion and interactive teaching methods, thereby limiting students' opportunities for engagement. Notwithstanding the fact that certain pedagogues may employ the use of questions in order to stimulate students' cognitive processes, the challenge of ensuring that each individual student is afforded sufficient opportunities for participation is often compounded by the considerable number of students in the classroom. It has been demonstrated that, over time, students' initiative in the classroom declines, and their thinking becomes less active.

2.3 Insufficient Modern Teaching Tools

The advent of information technology has precipitated the widespread adoption of contemporary pedagogical methodologies within educational settings. Nevertheless, it is noteworthy that conventional instructional materials classrooms continue to eschew the integration of contemporary technological tools. A significant number of courses continue to utilise blackboards and PowerPoint presentations, which are deficient in terms of interactivity and visualisation.

For instance, the utilisation of computer simulation, virtual experimentation and analogous contemporary technological tools in the pedagogy of mechanics of materials remains underdeveloped. Consequently, students encounter challenges in comprehending mechanical phenomena intuitively through these technologies. It has been demonstrated that traditional teaching methods have become increasingly unpopular amongst students, particularly when confronted with abstract mechanics theories. The dearth of contemporary teaching resources has been identified as a key factor in the diminution of students' learning experiences. In traditional classrooms, the utilisation of multimedia teaching tools such as animations, simulation software, and video presentations is seldom observed. It is evident that a significant proportion of abstract concepts in mechanics of materials, including mechanical models and deformation processes, prove challenging for students to comprehend when explanations are confined to textual and diagrammatic representations. The dearth of interactive teaching tools has been identified as a key factor in students' inability to visualize the integration of theory and practice, thereby impeding their comprehension and application of course material [3].

3. Reform Measures for Teaching Mechanics of Materials Course to Cultivate Applied Talents with Engineering Practice Ability

3.1 Optimize the Teaching Content of the Mechanics of Materials Course

In the process of cultivating applied talents, the setting of teaching content is crucial. For the mechanics of materials course, the teaching content should be closely integrated with engineering practice, highlighting the applicability and practicability. Specifically, optimizing the teaching content can be carried out in the following aspects:

3.1.1 Strengthening the combination of basic theory and practical problems

The conventional materials mechanics course places emphasis on theoretical explanations. However, in the context of engineering, students require instruction on how to apply theoretical knowledge to practical engineering problems. Consequently, there is a necessity to incorporate a greater proportion of content pertaining to authentic engineering cases within the curriculum. For instance, the incorporation of authentic engineering cases (e.g., construction, machinery, aerospace, and other fields of practical problems) into the curriculum facilitates students' comprehension of the theoretical underpinnings of mechanics of materials. Concurrently, it encourages them to contemplate the practical applications of these theories in problem-solving scenarios.

3.1.2 Increase in knowledge related to modern engineering technologies

In the contemporary era, the progression of science and technology has precipitated an augmentation in the demands placed upon materials utilised in the domain of modern engineering technology. Consequently, it is imperative that the curriculum of the mechanics of materials course incorporates a more substantial element of knowledge pertaining to contemporary engineering technology. For instance, there is a necessity to augment the incorporation of novel materials, state-of-the-art materials mechanics, nanomaterials, and other avant-garde technologies. This will facilitate students' comprehension of the most recent scientific research outcomes and the evolution of engineering technology. Consequently, it will enhance their capacity for innovation and their proficiency in engineering practice.

3.1.3 Strengthening the integration of interdisciplinary knowledge

The Mechanics of Materials course is of fundamental importance to students of mechanical and civil engineering, as well as other engineering disciplines, including environmental and chemical engineering. Consequently, the mechanics of materials course has the capacity to contribute interdisciplinary knowledge content that aligns with the requirements of diverse academic disciplines. For instance, students specialising in chemical engineering may benefit from an expansion of the curriculum to encompass the chemical properties and reaction mechanisms of materials, while those pursuing a degree in environmental engineering could find value in the incorporation of mechanical properties of materials in environmental conditions and corrosion problems. The implementation of such content facilitates the adaptable application of the principles of mechanics of materials in diverse engineering disciplines by students [4].

3.2 Reform Teaching Methods to Enhance Practicability and Interactivity

Traditional mechanics of materials courses are mostly based on classroom lectures and lack sufficient practical aspects. In order to improve students' engineering practice ability, the teaching method needs to be reformed, focusing on practicability and interactivity. Specific reform measures include:

3.2.1 Introduction of project-based teaching methodology

The project-based teaching method is predicated on the notion of a project-driven pedagogy, which emphasises the mastery of knowledge and skills through the execution of authentic projects. In the course on the mechanics of materials, projects related to actual engineering are designed so that students can solve practical problems in a team setting. For instance, a project on bridge design can be undertaken, which requires students to calculate the load capacity and stability of the bridge according to the given knowledge of mechanics of materials, and conduct experimental verification. The implementation of project-based teaching methodologies enables students to apply the theoretical knowledge they have acquired to specific engineering problems, thereby enhancing their practical abilities [5].

3.2.2 Increase experimental links and emphasize the combination of experiment and theory

The discipline of Mechanics of Materials is predicated on a combination of theoretical and experimental approaches, rendering experimental teaching a pivotal component in the students' learning process. In the context of teaching reform, an augmentation in the proportion of experimental courses, with an emphasis on the integration of experimental design and authentic engineering problems, constitutes a pivotal strategy to enhance students' practical capabilities. It is indeed feasible to devise experiments that accurately reflect the contemporary demands of engineering by enhancing the content and methodologies of existing experiments. For instance, experiments may be conducted to enhance the mechanical properties of diverse materials, including polymers and composites. Alternatively, experiments may be designed to emulate the stress of engineering structures, thereby facilitating student comprehension of the application of the mechanics of materials in practical settings.

3.2.3 Adding flipped classroom and online teaching sessions

The Flipped Classroom pedagogical approach involves a paradigm shift from the conventional educational model, wherein students acquire theoretical knowledge through independent study prior to class sessions. The physical classroom environment is then utilised for collaborative discussion, interactive learning activities, and problem-solving exercises. In the mechanics of materials course, some fundamental knowledge content can be allocated to the pre-course study phase, with further classroom instruction facilitated through group discussion, case study and other pedagogical methods to assist students in deepening their comprehension and practical application skills. Moreover, the integration of contemporary information technology facilitates the provision of augmented learning resources through the online teaching platform. Consequently, students are enabled to undertake independent study on the online platform and complete learning tasks according to their individual progress. This pedagogical approach has the potential to enhance students' independent learning abilities, while simultaneously promoting interactivity and practical application in the classroom environment [6].

3.3 Improve the Teaching Evaluation System and Emphasize the Evaluation of Comprehensive Quality

Teaching assessment is a part of teaching reform that can not be ignored. The traditional assessment method focuses too much on theoretical exams and ignores the practical ability and comprehensive quality of students. In the process of cultivating applied talents, the assessment system needs to be more diversified, not only examining the theoretical foundation of students, but also evaluating the engineering practical ability of students. Specific assessment reform measures can include:

3.3.1 Strengthening the assessment of practical skills

In the process of assessing students, greater emphasis should be placed on their practical and problem-solving abilities. For instance, in addition to the conventional final examination, practical forms of assessment such as project reports, laboratory reports and case studies can be incorporated. In the project report, students are required to conduct a detailed analysis of the project they have undertaken, demonstrating their application of knowledge in the field of mechanics of materials to the resolution of practical problems. In the experiment report, students are expected to provide a summary of the experimental results, analyse the collected data, and propose recommendations for enhancement. Furthermore, students' aptitude in real-world engineering scenarios can be evaluated through on-site assessments and engineering design competitions [7,8].

3.3.2 Introduction of peer review and self-assessment mechanisms

In addition to teacher assessment, the introduction of mechanisms such as peer review and self-assessment has the potential to promote interaction and self-reflection among students. In the context of group projects, students are subject to evaluation not only by teaching staff but also by their peers through a process of peer review. This approach facilitates the formulation of constructive comments, which contribute to the students' learning and development. This form of evaluation has been demonstrated to enhance students' collaborative abilities and critical thinking skills, in addition to assisting them in identifying areas for improvement within their engineering practice [9].

3.3.3 Focusing on the comprehensive quality of students

In addition to academic performance, a number of other factors have been identified as being integral components of engineering practice ability. These include innovative ability, teamwork spirit and communication ability in students. Therefore, when assessing students, their comprehensive quality can be examined through a variety of methods, including interviews, report presentations and practical achievements. For instance, students can be assigned different roles within a team, and tasked with role-playing and simulation exercises to evaluate their performance in a team context, as well as their communication skills and problem-solving abilities. These assessments of comprehensive quality have been shown to facilitate the training of students to become all-round applied talents [10].

4. Conclusion

In summary, the teaching reform of mechanics of materials courses should focus on the combination of theory and practice, and strengthen students' engineering practice ability and innovation ability. It is evident that the optimisation of teaching content, the reformulation of teaching methods and the perfection of the assessment system can result in the enhancement of students' comprehensive quality. Furthermore, the cultivation of adaptable talents that align with the requirements of society can be facilitated. In the future, teaching processes are required to undergo continuous promotion, innovation and improvement in order to keep pace with the constant changes in technology and social demand. This is especially important for the teaching reform of the mechanics of materials course, in order to cultivate more excellent engineering talents.

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References

[1] Chengjun Yan. Reform and practice of

teaching mechanics of materials course. Industry and Technology Forum,2024, 23(05): 193-196.
[2] Xintao Zhao. Teaching reform of courses based on the concept of OBE education--Taking "Mechanics of Materials" as an example. Neijiang Science and Technology, 2023, 44(07): 157-158.
[3] Shuying Qu, Longyu Lu, Liang Song, et al. Practice of Civic Teaching in Mechanics of Materials Courses--Taking "Stabilization of Compression Rods" as an Example. Mechanics and Practice, 2021, 43(6):959-963.
[4] Haifeng Liu, Junying Bai, Jialing Cha, et al. " Reform and Practice of Civics and Politics in Mechanics of Materials Course. Education and Teaching Forum, 2024(27):73-76.
[5] Fengchun WeiI, Sankui Xu, Jin Peng, et al. Teaching reform and practice of "on-line and off-line + course politics" in the course of mechanical properties of materials under the background of new engineering. Journal of Higher Education, 2023, 9(5):129-132.
[6] Lijie Zuo, Yunyun Shi, Yiqiang He, et al. Teaching Reform of Mechanical Properties of Materials Based on Applied Talent Cultivation. 2021(2020-32):143-145.
[7] Chaoying Lv, Xinyi Yang, Ying Li, et al. Teaching reform practice of mechanics of materials course based on the concept of application-oriented talent cultivation. Paper Equipment and Materials, 2024, 53(12):221-223.
[8] Zhijun Li, Xuehua Li, Xia Wang. Research on Teaching Reform of Mechanics of Materials in Civil Engineering Classes of General Colleges and Universities under Engineering Education Accreditation. Industry and Technology Forum, 2024, 23(17):148-151.
[9] Shijun Guo, Lanping Lu, Hongbo Liu. "Design and Practice of Teaching Civics in Mechanics of Materials. Education and Teaching Forum, 2023, (22):96-99.
[10]Weijie Li. Exploration of engineering application-oriented teaching reform of "Mechanics of Materials". Education and Teaching Forum, 2023, (22):49-53.