Global Research in Higher Education
ISSN 2576-196X (Print) ISSN 2576-1951 (Online)
Vol. 8, No. 2, 2025
www.scholink.org/ojs/index.php/grhe

Original Paper

Teaching Reform and Practice of "Structural Mechanics" Course under the Background of New Engineering Discipline

Xiaoxiao Sun[1], Jinxiu Hu[1], Huaken Zhang[1], Qingchi Zhang[1], Lijuan Chen[1] & Qun Liu[1]

[1] Qingdao City University, Qingdao, China

Received: May 30, 2025 Accepted: June 10, 2025 Online Published: June 15, 2025

doi:10.22158/grhe.v8n2p70 URL:http://dx.doi.org/10.22158/grhe.v8n2p70

Abstract

Under the background of the new engineering discipline construction promoting the transformation of engineering education, the traditional "Structural Mechanics" course has exposed pain points such as lagging content system, weak practical links, and single teaching methods. Based on the educational goal of the course, this paper proposes a three-dimensional teaching reform path oriented towards ability cultivation: through modular content reconstruction, organically connecting theoretical knowledge with engineering frontiers; by means of the blended teaching mode, building a multi-dimensional interactive learning ecosystem; relying on the optimization of the practical teaching system, enhancing students' ability to solve complex engineering problems; and establishing a diversified evaluation mechanism throughout the entire process, deeply integrating ideological and political elements into the mechanics knowledge system. Teaching practice shows that the reform effectively promotes the coordinated development of students' engineering literacy and innovative thinking, providing a reference implementation model for the connotation construction of professional basic courses under the background of new engineering disciplines.

Keywords

New engineering disciplines, structural mechanics, teaching reform, blended teaching, diversified evaluation, ideological and political education in courses

1. Analysis of the Current Teaching Situation of the Traditional "Structural Mechanics" Course

1.1 The Course Content Is Abstract and Complex, and Its Structural System Lags Behind the Demands of the New Era

The current knowledge framework of the "Structural Mechanics" course still centers on classical mechanics theories, mainly covering core modules such as static analysis, dynamic response, and stability calculation of bar structures. However, the course content shows a significant tendency towards theoretical abstraction, with most textbook examples being confined to traditional engineering fields like civil and industrial construction and bridges. There is a notable deficiency in coverage of emerging technologies such as intelligent construction, green structures, composite material structures, and prefabricated buildings. For instance, in mainstream textbooks, the integration of modern technologies like BIM collaborative design, structural health monitoring, and intelligent algorithm optimization is severely lacking, making it difficult for students to establish a mapping relationship between theoretical knowledge and modern engineering demands. This lag has led to a disconnection between course teaching and the core goals advocated by new engineering disciplines, such as "interdisciplinary integration" and "solving complex engineering problems". As a result, students often fail to transfer knowledge effectively when facing real-world engineering problems. For example, they experience cognitive overload due to having to memorize numerous formulas for solving statically determinate structures without a deep understanding of the fundamental principles of mechanics; there is a technological generation gap, with textbooks lacking content on the application of digital twins and machine learning in structural analysis; and there is a lack of interdisciplinary connections, with cross-disciplinary content such as composite material constitutive models and integrated structure-control design not being included in the knowledge system.

1.2 The Marginalization of Practical Teaching and the Absence of Innovation Ability Cultivation

The structural imbalance in the practical teaching system. Traditional courses position experimental classes as "tools for verifying theories", only setting up basic experiments such as deflection measurement of simply supported beams and internal force analysis of trusses. Students mechanically follow the operation procedures in the experimental manual, such as directly applying formulas to calculate after collecting data with a strain gauge, without exploring the sources of errors (such as the influence of temperature drift) or reflecting on the rationality of model simplification. Most students have never independently designed an experimental plan. More seriously, complex structure experiments (such as stability tests of large-span spatial structures) have been completely excluded due to the lack of equipment, resulting in students' understanding of real engineering problems remaining at the theoretical calculation level, lacking practical verification.

Innovation training is disconnected from engineering practice. The so-called “innovation link” often becomes a superficial exercise: course designs frequently adopt idealized propositions (such as “internal force calculation of steel trusses”), ignoring actual constraints (such as construction errors, material nonlinearity, etc.); software teaching is limited to software operation demonstrations (such as basic modeling in Midas), without training in parameter sensitivity analysis or model correction capabilities. For instance, in the analysis of statically indeterminate structures, students merely follow the steps to solve for internal forces, without considering questions like “the impact of a 2 cm settlement of the support on the bending moment distribution” or “how to reduce secondary internal forces through structural measures”. This kind of training divorced from real scenarios deprives students of the motivation to identify problems and optimize designs.

1.3 The Traditional Teaching Mode Leads To the Loss of Students’ Intrinsic Motivation

The traditional teaching model that is currently widespread, characterized by “teachers lecturing, students listening, practicing after class, and taking final exams”, is profoundly restricting students’ initiative in exploration and their motivation for in-depth learning. Its drawbacks are mainly reflected in the following aspects:

Passive reception replaces active construction, and the depth of cognition is limited. In the classroom, the one-way knowledge infusion places students at the receiving end of information. Students rarely have the opportunity to experience the complete scientific process of the formation of structural mechanics knowledge, such as “identifying problems - establishing models - theoretical derivation - solving and verifying”. For instance, when learning “force method for solving statically indeterminate structures”, students often mechanically memorize the typical equation forms and coefficient calculations, but find it difficult to actively think about their physical meaning (deformation coordination) and the logical necessity of the establishment process. Their understanding of the essence of knowledge remains superficial, which hinders the cultivation of critical thinking and knowledge transfer ability.

The disconnection between abstract theories and practical applications, along with a vague sense of learning significance: The concepts in structural mechanics are highly abstract. If traditional teaching lacks a strong connection to real engineering scenarios, students find it difficult to establish an effective link between symbols, formulas, and vivid engineering phenomena. This disconnection leads to learning becoming a dull mathematical calculation, and students cannot deeply understand “why they are learning”. As a result, the intrinsic value of learning and the desire to explore are naturally weakened.

The assessment methods are mostly standardized tests, which focus on testing students’ memory of theoretical knowledge and simple application, lacking the evaluation of students’ autonomous learning process, innovative thinking and complex problem-solving abilities. This makes it difficult to stimulate students' intrinsic motivation for in-depth study, ultimately affecting the cultivation of students' professional qualities and innovation capabilities.

1.4 The Teaching Methods Are Monotonous and Insufficiently Integrated With Information Technology

The lack of demonstration of complex mechanical phenomena leads to low cognitive efficiency among students. Core concepts in structural mechanics, such as moment distribution, instability modes, and dynamic response, are highly abstract and dynamic. However, traditional teaching methods present these concepts using two-dimensional diagrams or simple animations, making it difficult for students to understand and master them. For instance, when explaining the "moment envelope diagram of a continuous beam under moving loads", static diagrams cannot show the dynamic redistribution of internal forces caused by the change in load position. When analyzing "buckling instability of frame structures", the absence of three-dimensional interactive demonstration tools for multiple modal shapes leads to students' vague understanding of the instability mechanism. If finite element cloud rendering technology (such as ANSYS Workbench) is introduced, allowing students to adjust constraint conditions and observe the changes in stress flow, it can significantly enhance the efficiency of constructing complex concepts.

The experimental system for integrating virtual and real-world elements is fragmented, which restricts the cultivation of practical abilities. Traditional experiments are constrained by equipment scale and safety risks, and can only complete basic verification experiments such as simply supported beams and trusses. Meanwhile, virtual simulation platforms are often disconnected from physical experiments: after students calculate the internal forces of steel frames using Midas, they cannot verify the credibility of the results through physical models.

The intelligent learning diagnosis is lacking and the teaching regulation is lagging behind. The knowledge system of structural mechanics has a strong logical correlation. For instance, the force method is the foundation of the displacement method. However, in teaching, it is difficult for teachers to discover students' sticking points in real time - is it the weakness in the concept of the force method or the deviation in understanding the "principle of the displacement method"? There is a lack of precise diagnosis based on learning big data.

1.5 Course Assessment Is Dominated By Outcome-Based Evaluation, Emphasizing Results over the Process

The assessment form is monotonous. Most universities still use the final closed-book examination as the core evaluation method for courses. The assessment question types are mainly traditional short-answer questions and calculation questions, focusing on testing students' memory of formulas and standardized problem-solving steps (such as the method of virtual work, force method typical equations, etc.). This model is difficult to measure students' engineering thinking, innovative consciousness, and practical application ability. For example, in the assessment of "solving statically indeterminate structures by the force method", if only the application of fixed steps to solve internal forces is required, while the understanding of the "physical meaning of deformation compatibility conditions" or the "comparison and analysis of the applicability of different solution methods" is ignored, it is easy to make students mechanically answer questions and fail to truly understand and master the principles of structural mechanics.

The evaluation of practical ability has become superficial, and the disconnection between knowledge and action has intensified. Practical components such as course experiments and software modeling are often treated as "bonus points", with ambiguous scoring criteria (for instance, only based on the completeness of the experiment report), failing to truly reflect students' hands-on skills and engineering literacy. For example, in the experiment of measuring internal forces in truss structures, students might merely mechanically record data while neglecting error analysis. However, since the final exam does not cover practical details, such deficiencies in ability have long gone undetected and uncorrected.

2. The Objectives and Implementation Pathways of the Reform of the "Structural Mechanics" Course

2.1 Reconstruct the Course Content and Strengthen the Cultivation of Engineering Capabilities

2.1.1 The Deep Integration of Theoretical Teaching and Engineering Cases

Traditional courses tend to focus on mathematical derivations (such as the formula derivation of force method and displacement method), but downplay their engineering application background. After reconstruction, real cases can be embedded in theoretical teaching, such as explaining the principle of internal force redistribution in statically indeterminate structures by combining the "accident of bridge bearing settlement", or introducing the concept of structural dynamics through "wind vibration control of high-rise buildings", making abstract theories concrete and cultivating students' engineering thinking of "inferring the essence of mechanics from phenomena".

2.1.2 Introduce Modern Analytical Tools and Enhance Digital Capabilities

The current textbooks mostly provide only brief introductions to computer-aided analysis methods such as the finite element method. Practical operation modules for software like ANSYS and Midas should be added, requiring students to compare the results of manual calculations with those of software simulations (such as the deflection calculation of simply supported beams), analyze the sources of errors, and master the full-process ability of "theory - numerical model - engineering judgment" to adapt to the digitalization trend in the industry.

2.1.3 Design Open-Ended Practical Projects to Cultivate Comprehensive Qualities

Breaking the limitations of traditional "confirmatory experiments", interdisciplinary project tasks are set, such as "design and optimize a model of a pedestrian bridge given a budget and material constraints". Students need to independently complete load analysis, component selection, cost assessment and other links, strengthening their innovative awareness, teamwork and engineering economic thinking.

2.2 Build a Practical Teaching Platform to Enhance Innovative Application Capabilities

2.2.1 Construction of a Virtual-Reality Fusion Experiment Platform

Breaking through the limitations of traditional experimental equipment, a dual-track platform of "physical experiments + virtual simulation" is constructed. Physical experiments focus on basic skills training, such as strain gauge bonding and load testing; the virtual simulation platform, on the other hand, uses software like ANSYS and ABAQUS to simulate complex engineering scenarios (such as seismic analysis of long-span structures). The two platforms share data, forming a closed-loop training mode of "measurement - simulation - optimization".

2.2.2 Digital Capability Development Module

Add a BIM technology integrated application section, requiring students to visually present the results of mechanical analysis and achieve collaborative work with design software such as Revit. Develop a mobile AR program that can display the internal force distribution of a structure by scanning it, enhancing spatial understanding ability.

2.2.3 Construction of the Industry-University-Research Collaboration Platform

Jointly build practice bases with design institutes and construction enterprises, and transform actual engineering problems into teaching cases. Introduce the "enterprise mentor system", and jointly guide graduation projects to ensure that the topics are derived from real project demands.

2.3 Reconstructing the Classroom Teaching Model with Students at the Center

In terms of organizing teaching content, the original chapter sequence is broken and the teaching content is restructured. The principle of coming from engineering and going back to engineering is followed, and the chapters are divided according to different force-bearing structural systems. Before class, students learn through micro-lesson videos to understand the application of structures in engineering and stimulate their interest in learning. During class, teachers raise relevant engineering problems, guide students to think and discuss, and find answers from classroom learning to cultivate students' ability to analyze and solve problems. After class, project tasks are assigned, requiring students to use virtual simulation platforms to simulate engineering scenarios. Students can transform complex structural mechanics problems into intuitive graphics and animations. This visual teaching can improve students' learning quality. In this process, teachers mainly play the role of learning guides and resource providers, and help students gradually build a complete knowledge system by setting up a step-by-step problem chain.

2.4 Integrate the "Online + Offline" Multi-Dimensional Classroom Organically and Build an Information-Based Learning Environment

From the perspective of online teaching resource construction, the online platform needs to systematically integrate three types of core resources: micro-lectures (10-15-minute videos focusing on key and difficult points), interactive simulation modules (such as real-time bridge load simulation systems), and adaptive question banks (which intelligently push exercises based on students' answer data). Taking the teaching content of "influence lines" as an example, students can first understand the mechanism of moving loads through online animation demonstrations, then enter the virtual laboratory to independently adjust parameters and observe the internal force change patterns, and finally complete personalized customized calculation exercises. This combination of resources not only ensures the systematicity of knowledge transmission but also meets the differentiated learning needs.

In terms of classroom teaching organization, a hybrid model of "flipped classroom + project-driven" is adopted. The offline classroom time is mainly used for in-depth discussions and engineering practices, such as analyzing the actual force conditions of a bridge or the failure mode of a building under natural disasters. The role of teachers shifts from knowledge transmitters to learning guides, who set targeted question chains to guide students to apply the theories learned online to solve problems. At the same time, the real-time feedback system of smart classrooms is utilized to dynamically grasp students' learning progress and adjust teaching strategies.

2.5 Establish a Diversified Assessment and Evaluation Mechanism to Implement the Goal of Ideological and Political Education in Courses

2.5.1 Establish a Diversified Assessment and Evaluation Mechanism

The assessment content covers three aspects: knowledge assessment, ability assessment, and quality assessment. The knowledge assessment mainly examines students' mastery of mechanics principles, accounting for 60%. The ability assessment includes experimental operations, group assignments, and engineering case analyses, accounting for 30%, and focuses on evaluating students' ability to solve practical problems. The quality assessment includes innovative design and professional ethics, accounting for 10%, aiming to cultivate students' innovative ability and engineering ethics awareness.

2.5.2 The Integration Methods of Innovative Process Evaluation and Ideological and Political Education

The form of "course diary + project defense" is adopted, requiring students to record their thoughts on major national engineering cases such as the "anti-seismic design of the Hong Kong-Zhuhai-Macao Bridge" in their learning logs, and to reflect the concept of sustainable development in group projects. Teachers guide students' professional abilities and ideological and political qualities through dynamic evaluation scales.

3. Conclusion

Under the impetus of the new engineering discipline construction, the reform of the “Structural Mechanics” course is centered on the core concepts of “ability reconstruction, technology empowerment, and value elevation”, and has established an innovative teaching system that integrates three aspects. In the dimension of ability cultivation, it breaks through the traditional “theory + exercises” framework, and through a closed-loop training chain of “anchoring engineering problems - mechanical modeling and deduction - software simulation verification - multi-objective optimization decision-making”, enhances students’ ability to solve complex engineering problems. In the dimension of technology integration, it builds a virtual-real interactive platform of “physical experiments - digital twins - intelligent feedback”, visualizes the stress field with AR technology, and generates personalized problem-solving paths based on learning behavior data, thus resolving the cognitive difficulties of abstract concepts. In the dimension of value shaping, it innovates a dual-track evaluation mechanism of “technology – ethics”, combining the safety factor of structures with the sustainability analysis of materials. This reform has achieved a qualitative change from knowledge transmission to the cultivation of engineers’ qualities, providing a replicable model for the construction of new engineering courses - deconstructing knowledge barriers with cutting-edge technologies, tempering practical abilities through real projects, and solidifying professional foundations through ethical reflection, ultimately responding to the strategic demand of the new era for compound engineering talents.

References

Cao, Y. M., Yu, G. L., Jia, Y., & Xu, Y. Q. (2023). Reform and Practice of the First-Class Course of Structural Mechanics with “Two Centers, Three Stages, and Four Levels” Structure. *University Education*, (07), 42-46.

Chen, D. D., Wang, Y., Wang, L. B., & Zhang, Y. T. (2023). Innovative Practical Teaching of Engineering Courses under the Background of New Engineering Education: A Case Study of “Structural Mechanics”. *Talent Intelligence*, (14), 69-72.

Jiang, S. Y., Jin, R., Yang, H. X., & Sun, L. G. (2023). Teaching Design of Structural Mechanics Based on Blended Teaching and Ideological and Political Education in Curriculum. *Higher Education Journal*, (33), 108-111.

Lin, Y., Zhang, Z., & Fan, X. S. (2023). Teaching Reform and Practice of Structural Mechanics Course Based on OBE Concept. *Journal of Taiyuan Urban Vocational College*, (11), 112-114.

Ren, J. Y., Zhang, Y., Yang, C. J., & Li, H. Y. (2024). Research on Ideological and Political Teaching of Structural Mechanics Course in the New Era. *Journal of Higher Education*, (01), 174-177.

Sun, L. (2021). Exploration of the Path of Industry-Education Integration for Talent Cultivation under the Background of New Engineering. *Jiangsu Higher Education*, (01), 80-83.

Wu, F., Wu, C., & Zhu, Q. (2022). Promoting the Cultivation of Innovative AI Talents through the Integration of Science and Education and the Synergy of Industry and Education. *China University Teaching*, (Z1), 17-21.

Zhang, J. J. (2023). Exploration of Structural Mechanics Course Construction for Mechanics Majors. *Higher Education Journal*, (19), 101-105.

Published by SCHOLINK INC.