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

Reform of Structural Mechanics Course Oriented by Engineering Practice and Integrated with Interesting Mechanics Experiments

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Received: May 20, 2025 Accepted: May 27, 2025 Online Published: May 30, 2025
doi:10.22158/grhe.v8n2p48 URL:http://dx.doi.org/10.22158/grhe.v8n2p48

Abstract
Under the background of engineering education accreditation and the development of new engineering disciplines, traditional structural mechanics courses are confronted with problems such as the disconnection between theory and practice, a monotonous teaching mode, and low student engagement. This study proposes a reform framework for structural mechanics courses that integrates interesting mechanics experiments. By Reconstructing teaching content, innovating teaching methods, and optimizing the evaluation system, a "theory-practice-political ideology" teaching model is constructed, providing strong support for better cultivating applied talents.
Keywords
structural mechanics, engineering practice, interesting mechanics experiment, curriculum reform, OBE concept

1. Introduction

1.1 Research Background

With the advancement of the construction of new engineering disciplines and the implementation of engineering education accreditation, higher engineering education is facing a paradigm transformation from "knowledge imparting" to "ability cultivation". Structural mechanics, as a core basic course for civil engineering, intelligent construction and other majors, plays a "bridging" role in connecting theoretical mechanics, material mechanics and subsequent professional courses such as the design principles of steel structures. Its teaching effect is directly related to the cultivation of students' ability to solve complex engineering problems.

However, the traditional teaching mode has problems such as the disconnection between theory and practice, insufficient classroom interaction, and low students' learning motivation. Although some universities have attempted to carry out teaching reforms through multimedia teaching or case introduction, it is still difficult to break through the predicament of low students' classroom participation and weak knowledge transfer ability. This contradiction has become increasingly prominent under the background that engineering education emphasizes practicality and innovation, and it is urgent to explore new teaching paths through systematic curriculum reform.

1.2 Research Significance

This study proposes a framework for the curriculum reform of structural mechanics integrating interesting mechanics experiments. Its significance is reflected in the following three aspects.

By introducing engineering cases and applying PKPM engineering design software to drive teaching, students' ability to apply mechanics theories to practical problems is strengthened, which is in line with the core requirement of "outcome-oriented" under the OBE concept.

The integration of interesting mechanics experiments can stimulate learning interest through life-like scenarios, break the deadlock of "one-way indoctrination" in traditional classrooms, and enable students to truly experience the principles of mechanics through hands-on and brain-stimulating activities. At the same time, it can enhance the team's innovative awareness through group collaboration.

By combining ancient architectural wisdom with modern engineering achievements, a library of ideological and political elements is constructed. Engineering ethics and social responsibility are integrated into professional education to achieve an organic unity of knowledge imparting and value guidance.

This research not only provides an operational practical path for the curriculum reform of structural mechanics, but also lays a theoretical foundation for the collaborative innovation of interdisciplinary courses under the background of new engineering, which has important academic value and significance for the promotion of engineering education.

2. Analysis of Problems in Traditional Structural Mechanics Teaching

2.1 Summary of Teaching Pain Points

Structural mechanics, as a theoretical course supporting the major, is closely related to engineering practice. Its core objective lies in cultivating students' ability to solve practical engineering problems by applying the principles of mechanics. However, in the current teaching, there is a widespread tendency of "emphasizing theoretical derivation while neglecting practical application". For instance, although students can proficiently calculate the bending moment and shear force of statically and precisely structured structures, when it comes to the design of complex structural models, they often have no idea where to start and find it difficult to transform abstract formulas into engineering design logic.

Traditional classrooms mostly adopt the linear model of “teacher lecturing-students listening and taking notes”. Even though teaching reforms have been carried out, “teacher lecturing” still occupies the vast majority of class time, and there is a lack of teaching interactivity and innovation. The teaching method mainly based on “blackboard derivation + example problem explanation” is difficult to stimulate students’ awareness of active exploration. Studies show that one-way indoctrination

Structural mechanics requires theoretical mechanics and material mechanics as the prerequisite foundations. However, among the student group, it is inevitable that there is a phenomenon of not firmly grasping the prerequisite knowledge. Some students are unable to proficiently draw the force analysis diagram of the structure or establish the equilibrium equation, which hinders the subsequent learning of the internal force analysis module of the structure. This fundamental difference further exacerbates the imbalance between teaching progress and effect.

At present, ideological and political elements in teaching are mostly limited to the mention of scattered cases, lacking systematic design and in-depth integration. The separation of value guidance and professional education makes it difficult for students to form a profound understanding of engineering ethics and social responsibility, and there is a gap with the educational goal of “cultivating virtue and nurturing talent”.

2.2 Root Cause of the Problem

The traditional teaching mode is teacher-centered, and students have become passive recipients. This concept ignores the differences in individual learning needs and inhibits the cultivation of critical thinking and innovation abilities. The assessment overly relies on closed-book written tests and fails to reflect the teamwork and problem-solving abilities required in engineering practice.

With the rapid development of emerging fields such as intelligent construction and green buildings, the update speed of the content of structural mechanics courses lags significantly. The textbooks still mainly focus on classic structural analysis, and rarely cover cutting-edge technologies such as structural health monitoring. Furthermore, the teaching evaluation system fails to align with the assessment requirements for “the ability to solve complex engineering problems” in engineering education accreditation, resulting in a disconnection between talent cultivation and industry demands.

There is a lack of organic connection of the knowledge system between structural mechanics and the prerequisite courses as well as the subsequent courses. The correlation between “force analysis of objects” in theoretical mechanics and “solving internal forces of structures by section method” in structural mechanics has not been made explicit, making it difficult for students to construct a systematic cognitive framework of mechanics.

3. The Core Concept of the Curriculum Reform of Structural Mechanics

3.1 Student-centered

The inertial thinking of “teachers dominating the classroom” in the traditional teaching mode urgently needs to be broken through. This research adopts the concept of “student-centered”, emphasizing the reconstruction of the teaching process through the intelligent empowerment of knowledge graphs and autonomous inquiry-based learning.

Based on the learning theory, the knowledge points of structural mechanics are visually presented by using knowledge graph technology to help students establish a systematic knowledge framework.

The group cooperative learning and flipped classroom models are adopted to shift the classroom time from one-way lectures to problem discussions. In the teaching of internal force analysis, a situational task of “Failure of Bridge Bearings” is set up. The group is required to propose solutions through model construction and mechanical derivation, and the teacher only participates in the discussion as a guide. The practice of this concept not only conforms to the goal of cultivating cognitive ability, but also effectively alleviates the chronic problem of “scattered attention” in traditional teaching by enhancing the sense of classroom participation.

3.2 Oriented towards Engineering Practice

To bridge the gap between theory and practice, curriculum reform needs to closely align with the demands of engineering practice and build a teaching ecosystem that integrates learning and application. Select typical engineering problems as teaching carriers, and combine the case of the “Harbin Yangmingtan Bridge Accident” to guide students to apply the basic principles of statics to conduct in-depth analysis of the causes of the accident, achieving the expansion training of “mechanics theory-engineering practice”.

In accordance with the standards of the College Students’ Structural Design Competition, organize the load-bearing design competition of truss Bridges within the course. Students are required to comprehensively apply knowledge such as the mechanical properties of materials, geometric structure analysis, and force analysis of truss structures to complete model design and loading tests, and to hone their abilities in structural optimization and teamwork in real engineering scenarios. This orientation not only strengthens students’ engineering thinking, but also promotes the transformation of knowledge into ability through the “learning by doing” model.

3.3 The OBE (Outcome-based Education) Concept

Based on the OBE concept, the curriculum reform needs to reverse design the teaching system starting from the learning outcome goals. According to Bloom’s Taxonomy of Educational Objectives, the ability requirements are decomposed into three levels of objectives: “Memorizing the characteristics of statically determinate structures-analyzing statically determinate structures-designing and optimizing complex systems”, and corresponding teaching activities are matched.

Abandon the single closed-book examination and adopt a diversified evaluation model of "process performance + practical achievements + comprehensive written test" to ensure that the assessment content is consistent with the ability requirement of "solving complex engineering problems" in engineering education accreditation. The implementation of this concept shifts teaching from "knowledge coverage" to "ability achievement", providing quantifiable quality assurance for engineering education accreditation.

4. Reform Strategies and Implementation Paths

4.1 Reconstruction of Teaching Content

In order to achieve the coordinated improvement of the knowledge system and engineering practice ability, the teaching content is systematically reconstructed and divided into the basic knowledge module, the structural system module and the computerized analysis module. Integrate the core concepts of theoretical mechanics and material mechanics in the basic knowledge module, and enhance the ability to analyze geometric structures and draw calculation diagrams. By comparing the constraint conditions of trusses and rigid frames, guide students to understand the engineering significance of "degrees of freedom" and "constraints".

The mechanical characteristics of different structural systems such as beams, trusses, arches, rigid frames and frames are analyzed hierarchically in the structural system module. For instance, in the teaching of "Arch Structure Analysis", the case of catenary arch bridge is introduced. Combined with the derivation of differential equations and numerical simulation, students' understanding of the distribution laws of axial force and bending moment is deepened.

The PKPM application training is embedded in the computer analysis module, requiring students to use PKPM to complete the load combination calculation of the steel structure factory building and improve the structural economy through parameter optimization.

4.2 Innovation in Teaching Methods

Adopt a blended teaching mode combining online and offline. Relying on the Chaoxing Learning Pass platform online, we have developed a dual-driven online resource system of "micro-lesson videos + exercise banks", creating micro-lessons such as "Force Analysis of Objects" and "Calculation of Internal Forces of Trusses by Node Method". Students can watch and study at any time and self-test their learning effects with exercises. Teachers can prepare lessons in a targeted manner through data analysis in the background.

Offline, case-based teaching is relied on. Typical engineering cases are selected as the teaching entry point to guide students to analyze the failure mechanism from the perspective of mechanics and propose solutions.

To break the dullness of traditional classrooms, this study proposes to deeply integrate life-related and interesting experiments into teaching and visually reveal the principles of mechanics through simple experiments. For instance, when explaining the balance of force, students are required to build a support system with matches and suspend mineral water bottles to test the load-bearing limit. Through the experimental data, they can infer the law of force analysis.

4.3 Optimization of the Assessment and Evaluation System

Change the traditional evaluation method mainly based on the final exam, strengthen the process assessment, and divide the assessment content into three parts: learning process evaluation, practical ability assessment and the final comprehensive test. The process assessment accounts for 25%, covering online learning activity, classroom interaction performance and phased tests. The assessment of practical ability accounts for 35%, including competition achievements and computerized analysis reports. The final comprehensive test accounts for 40% and is conducted in a “semi-open-book” format. Self-made knowledge cards are allowed, with a focus on assessing the comprehensive analysis ability of complex engineering problems.

Real-time tracking of learning data is achieved through the Chaoxing Learning Pass smart Course platform, and personalized learning reports are automatically generated by AI teaching assistants. For students with weak mastery of certain knowledge points, targeted supplementary exercises and micro-lesson resources are pushed. Establish a three-level feedback channel of “teacher-teaching assistant-student”, and solve common problems through weekly learning salons to ensure that problems are not left overnight.

4.4 Implementation of Ideological and Political Education in Courses

Taking ancient buildings such as Zhaozhou Bridge and Yingxian Wooden Pagoda as examples, this paper analyzes their mechanical principles and the spirit of craftsmanship, guiding students to appreciate the engineering value of “striving for excellence”. Analyze the technological innovations behind super projects such as the Shanghai Tower and strengthen the sense of mission of “serving the country through science and technology”. In the chapter of “Structural Stability”, combined with the two collapse incidents of the Quebec Bridge, the social responsibility and professional ethics of engineers are explored. In the truss bridge design competition, a “sustainable development” scoring item has been added, requiring students to demonstrate environmental friendliness from dimensions such as material selection and construction techniques, and cultivating the awareness of green engineering.

5. Conclusions and Prospects

5.1 Conclusion

This research takes the cultivation of engineering practice ability as the core goal. Through systematic reconstruction of teaching content, innovation of teaching methods and optimization of the evaluation system, a three-in-one curriculum reform framework of "theory-practice-ideological and political education" for structural mechanics has been constructed, and the following core achievements have been made:

(1) Guided by the OBE concept, through strategies such as "engineering case-driven" and "integration of interesting experiments", the chronic problem of the disconnection between theory and practice in traditional teaching has been effectively solved. Students are not only capable of analyzing complex structural problems based on mechanical principles, but also demonstrate remarkable engineering practice abilities in the operation of computer tools and the optimization design of structures.

(2) Enhancement of learning motivation and innovation ability. The implementation of the blended teaching mode and group collaborative tasks has effectively enhanced classroom participation. Students performed outstandingly in the discipline competition of intelligent building structure design, verifying the effectiveness of the "learning by doing" concept.

(3) Deep integration of ideological and political education in courses. Through the multi-dimensional infiltration of ancient architectural wisdom, modern engineering achievements and the spirit of scientists, students' sense of social responsibility and engineering ethics have been significantly enhanced.

5.2 Future Directions

To further deepen the curriculum reform, continuous exploration is needed from the following dimensions:

(1) Cross-curriculum collaborative reform to promote the integration of the knowledge systems of structural mechanics with prerequisite courses and subsequent courses. The reconstruction of course knowledge has been integrated into the core contents of statics and mechanics of materials. In subsequent professional courses such as steel structure design, structural mechanics optimization algorithms can be introduced to construct an integrated teaching chain of "analysis-design-verification".

(2) Artificial intelligence technology empowers teaching. Based on the Chaoxing Learning Pass smart course platform, a personalized learning path recommendation system is constructed.

(3) Deepen the integration of industry and education, promote the entry of enterprise real questions into classrooms, cooperate with design institutes, construction enterprises and building technology enterprises, transform practical engineering problems into course tasks, and invite engineers to participate in the review of achievements.

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