

Original Research Article

Research on teaching reform of civil engineering materials experimental course under the background of emerging engineering education

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Abstract: Driven by emerging engineering education construction and engineering education certification, traditional experimental teaching of civil engineering materials faces prominent problems, including outdated teaching content, dominant confirmatory experiments, rigid teaching modes, single assessment mechanisms, and insufficient integration of cutting-edge technologies and moral education. These shortcomings fail to meet the industry demand for innovative and high-quality civil engineering talents under green, intelligent, and industrial transformation. Based on the Outcome-Based Education (OBE) concept, this study proposes a systematic teaching reform framework covering hierarchical content optimization, online-offline blended teaching, whole-process diversified assessment, in-depth curriculum ideological and political integration, and open laboratory and production-education integration. Comparative teaching practice indicates that the reform significantly improves students' practical operation ability, innovative thinking, and comprehensive engineering literacy, thereby promoting overall teaching quality. The findings can provide practical and theoretical references for the experimental teaching optimization of civil engineering majors in local universities.

Keywords: civil engineering materials; experimental teaching; teaching reform; emerging engineering education; curriculum ideology and politics

1. Introduction

Civil engineering materials experiment serves as a fundamental practical course for civil engineering disciplines, bridging professional theoretical knowledge and on-site engineering practice. Its teaching quality substantially influences the cultivation of students' experimental detection capacity, engineering analysis thinking, problem-solving ability, and professional responsibility.

With the rapid transformation of the construction industry toward low-carbon development, intelligent construction, and prefabricated architecture, higher requirements have been raised for the practical competence, innovative capability, and comprehensive literacy of civil engineering practitioners. However, conventional experimental teaching in most universities remains teacher-dominated and content-conservative, with outdated experimental projects, rigid teaching procedures, and passive student participation. The over-reliance on confirmatory experiments and the lack of innovative and design-oriented training result in students' insufficient engineering adaptability and innovative potential, which cannot satisfy the talent cultivation standards of emerging engineering education and professional certification. Therefore, systematic teaching reform is essential to improve the practical teaching level and cultivate industry-competent engineering talents.

2. Existing problems of traditional experimental teaching

2.1. Outdated experimental content system

Traditional experimental items mainly focus on conventional performance tests of cement, concrete, and steel materials, with long-term stagnation in content updating. Experimental projects related to recycled building materials, low-carbon cementitious materials, and solid waste utilization are seriously lacking. Meanwhile, frontier testing technologies, including microscopic characterization and intelligent non-destructive detection, are rarely involved in classroom teaching. Consequently, students' knowledge systems fail to keep pace with the technological upgrading of the modern construction industry.

2.2. Unreasonable experimental structure and training mode

The experimental structure is severely imbalanced, with confirmatory experiments accounting for more than 80% of the total curriculum. Comprehensive design experiments and innovative exploratory experiments occupy an extremely low proportion. In traditional teaching, students merely follow standardized operating procedures provided by teachers to complete tests, record data, and write reports. The lack of independent scheme design, fault diagnosis, and in-depth data analysis training restricts the development of students' innovative thinking and engineering problem-solving ability.

2.3. Rigid and single teaching mode

Current experimental teaching still relies on offline demonstration and repetitive imitation. Information-based teaching methods such as virtual simulation, online preview, and engineering case teaching are not fully applied. The monotonous teaching atmosphere leads to low student participation, insufficient pre-class preparation, and inadequate after-class expansion. Such a passive learning mode greatly limits learning initiative and innovative inspiration.

2.4. Simplified and incomplete assessment system

Traditional assessment adopts a typical summative evaluation mode, which mainly depends on final examination results and experimental report scores. Process-based indicators, including operation standardization, original data authenticity, team collaboration, and innovative performance, are ignored. This one-sided evaluation cannot objectively reflect students' comprehensive abilities and learning attitudes, thus lacking effective guidance and incentive functions for practical teaching.

2.5. Superficial integration of curriculum ideology and politics

Traditional teaching overemphasizes professional skill training while neglecting literacy cultivation. Core educational elements, such as engineering safety awareness, green low-carbon concepts, craftsman spirit, and professional ethics, are not effectively integrated into experimental procedures. The separation of professional teaching and moral education results in insufficient cultivation of students' sense of social responsibility and engineering literacy.

3. Reform framework and training objectives

3.1. Overall reform framework

Guided by the OBE concept and oriented toward emerging engineering education certification standards, this reform breaks the limitations of traditional experimental teaching. A four-level progressive teaching system consisting of basic verification, comprehensive design, innovative exploration, and engineering application is constructed. By implementing online-offline blended teaching, establishing whole-process multi-dimensional assessment, integrating curriculum ideological and political education, and promoting laboratory opening and school-enterprise cooperation, the reform realizes the coordinated cultivation of students' practical ability, innovative quality, and professional literacy.

3.2. Training objectives

Knowledge objectives: To enable students to master basic properties of mainstream civil engineering materials, national testing specifications, and standardized operating procedures; to understand the technical principles of green building materials and intelligent detection technologies.

Ability objectives: To cultivate students' capabilities of independent experimental design, standardized operation, data analysis, and result discussion; to improve their ability to solve practical engineering problems.

Literacy objectives: To foster rigorous academic attitudes, dedicated craftsman spirit, engineering safety awareness, and green sustainable development concepts, as well as enhance team collaboration and professional responsibility.

4. Specific reform measures

4.1. Construction of hierarchical modular experimental system

The experimental contents are divided into three progressive modules to achieve stratified training. The compulsory basic verification module retains classic experiments to consolidate students' fundamental

operational skills and normative awareness. The comprehensive design module adds innovative practical items, including concrete durability testing, recycled concrete proportion design, and non-destructive testing, requiring students to complete independent scheme design and variable control in groups. The optional innovative expansion module focuses on frontier research of new green building materials and solid waste resource utilization, supporting students to carry out innovative research based on discipline competitions and college innovation projects.

4.2. Implementation of online-offline blended teaching mode

A closed-loop teaching mode of pre-class online preview, in-class refined teaching, and post-class extended learning is established. Before class, online platforms release micro-lessons, industry specifications, and preview exercises to ensure adequate preparation. In class, teachers prioritize on-site demonstration, group practice, and engineering case analysis to integrate theoretical knowledge with practical scenarios. After class, online tutoring and academic expansion are provided to encourage students to explore innovative research topics.

4.3. Establishment of whole-process diversified evaluation system

A comprehensive evaluation system with a total score of 100 points is constructed, including preview performance (15 points), on-site operation (30 points), experimental report quality (25 points), innovative practice (20 points), and comprehensive professional literacy (10 points). This multi-dimensional evaluation realizes full-process monitoring and fair assessment of students' learning performance, effectively overcoming the defects of traditional summative evaluation.

4.4. In-depth integration of curriculum ideological and political education

Multiple moral education elements are embedded throughout the teaching process. Engineering safety accident cases are adopted to strengthen students' quality responsibility awareness. Green low-carbon concepts are integrated into recycled material experiments to cultivate sustainable development thinking. Group cooperative training enhances team spirit, and craftsman spirit stories guide students to establish rigorous and dedicated professional attitudes.

4.5. Promotion of open laboratory and production-education integration

Laboratories are open to students in spare time to support independent experimental exploration and innovative research. Through in-depth school-enterprise cooperation with testing institutions and construction enterprises, real engineering testing projects are introduced into classroom teaching. Industry engineers are invited to guide practical training, narrowing the gap between campus teaching and industrial demands and improving students' post adaptability and engineering practice ability.

5. Teaching effect analysis

A one-semester comparative teaching experiment was conducted on two parallel undergraduate classes. The results show that the experimental class achieves a 9.5-point increase in average comprehensive score and a 14.8% increase in practical operation qualification rate compared with the control class. More than 80% of students in the experimental class can independently complete comprehensive design experiments with improved data analysis, fault troubleshooting, and engineering problem-solving abilities. In addition, students demonstrate higher learning initiative, broader cognition of cutting-edge green building and intelligent detection technologies, and stronger professional responsibility and environmental awareness. The reform proves effective in optimizing the practical teaching system and improving comprehensive talent cultivation quality.

6. Conclusion and prospect

The teaching reform of civil engineering materials experimental course is an effective approach to adapt to emerging engineering education requirements and industrial transformation demands. The optimized teaching system solves the drawbacks of traditional rigid, outdated, and single-dimensional teaching modes. It effectively stimulates students' autonomous learning enthusiasm, improves their engineering practical ability and innovative thinking, and enhances their comprehensive professional literacy.

In future teaching practice, the experimental content will be dynamically updated according to industrial technological progress. Virtual simulation teaching resources and school-enterprise collaborative mechanisms will be further improved to establish a long-term teaching quality improvement mechanism, promoting the high-quality and innovative development of civil engineering materials experimental teaching.

Fundings

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