Global Education Development Study, 2026, Volume 2, Issue 1
https://ojs.bbwpublisher.com/index.php/GEDS
Online ISSN: 3083-3965
Print ISSN: 3083-3973

School-Enterprise Collaborative Teaching Reform and Practice of Civil Engineering Materials Course Serving the "Dual Carbon" Strategy

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Abstract: Against the backdrop of the comprehensive advancement of the "dual carbon" strategy, the demand for professionals with low-carbon concepts and practical abilities in the civil engineering industry is becoming increasingly urgent. This paper addresses issues in traditional course teaching, such as insufficient integration of the "dual carbon" concept, disconnection between theory and industrial practice, and the lack of a school-enterprise collaborative mechanism. It proposes a four-in-one school-enterprise collaborative teaching reform plan, namely "conceptual guidance–content reconstruction–mode innovation–platform support". By clarifying the objectives of curriculum reform, reconstructing the curriculum content system that incorporates low-carbon elements, innovating the collaborative teaching model of "classroom + enterprise + project", and building a practical teaching platform jointly constructed by schools and enterprises, it effectively enhances students' low-carbon literacy and engineering practical abilities, providing talent cultivation support for the civil engineering major to serve the national "dual carbon" strategy.

Keywords: Dual carbon strategy; Civil engineering materials; School-enterprise collaboration; Teaching reform; Talent cultivation

Online publication: Apr 7, 2026

1. Introduction

In September 2020, China clearly set the strategic goal of "striving to peak carbon dioxide emissions by 2030 and achieving carbon neutrality by 2060" (referred to as the "dual carbon" strategy). As a key sector for energy consumption and carbon emissions, the civil engineering industry accounts for more than 50% of the country's total emissions, covering the entire lifecycle stages such as building material production, construction, operation, and maintenance [1]. Among them, civil engineering materials, as the material basis for engineering construction, have their production processes (such as cement, steel, concrete, etc.) accounting for 60% to 70% of the industry's total emissions, making them a critical breakthrough point for achieving the "dual carbon" goals [2]. As the main base for talent cultivation, universities bear the important mission of supplying high-quality professionals to the industry. The civil engineering materials course, as a core foundational course of the major, mainly teaches the composition, properties, applications, and quality control of cement, concrete, steel, wood, new materials, etc., serving as an important bridge connecting theoretical knowledge with engineering practice [3]. However, there are numerous issues in traditional course teaching that are incompatible with the "dual carbon" strategy: Firstly, the course content emphasizes the basic properties and conventional applications of materials, lacking knowledge related to the "dual carbon" goals, such as low-carbon materials, green building materials, and carbon footprint accounting. Secondly, the teaching mode primarily relies on theoretical instruction in the classroom, with weak practical teaching components, making it difficult for students to access low-carbon technologies and application scenarios at the forefront of engineering. Thirdly, the school-enterprise collaboration mechanism is inadequate, with low enthusiasm from enterprises in participating in teaching, which prevents the integration of the latest industry needs and technological trends into the curriculum [4]. Therefore, carrying out school-enterprise collaborative teaching reforms in civil engineering materials courses to serve the "dual carbon" strategy holds significant practical importance and urgency.

2. Issues in traditional civil engineering materials course teaching

2.1. Insufficient integration of the "dual carbon" concept and outdated course content

The traditional civil engineering materials course content is centered around the logic of "material properties–applications–quality control", primarily focusing on traditional materials such as cement, concrete, and steel, lacking systematic integration of knowledge related to the "dual carbon" strategy. Specific manifestations include: Firstly, it does not cover the properties and applications of low-carbon materials (such as low-carbon cement, solid waste-based building materials, and bio-based materials). Secondly, it lacks theories and methods for calculating the carbon footprint throughout the entire lifecycle of materials (such as carbon emissions calculations in raw material extraction, production, transportation, construction, and disposal). Thirdly, it provides insufficient introduction to industry low-carbon policies (such as the "Green Building Evaluation Standards" and the "Administrative Measures for the Promotion and Application of New Building Materials") and technological trends (such as 3D-printed building materials and intelligent building materials), resulting in a disconnect between students' knowledge systems and industry needs [5].

2.2. Disconnection between theory and practice, with weak practical teaching components

Civil engineering materials is a highly practical course that requires experimental, internship, and project practice sessions to help students understand the relationship between material properties and engineering applications. However, traditional teaching suffers from the problem of "emphasizing theory over practice": Firstly, experimental teaching content primarily consists of verification experiments (such as cement fineness determination and concrete compressive strength tests), lacking innovative and comprehensive experimental projects (such as optimizing the mix ratio of low-carbon concrete and improving the performance of recycled aggregates). Secondly, the venues for practical teaching are confined to on-campus laboratories, making it difficult for students to be exposed to real-world material application scenarios in engineering (such as construction sites for low-carbon buildings and production workshops for green building materials). Thirdly, practical teaching sessions are brief (with experimental classes accounting for only about 20% of the total class hours in most universities), and there is a lack of professional practical teaching instructors, hindering the improvement of students' practical abilities [6].

2.3. Lack of school-enterprise collaboration mechanisms and low corporate participation

School-enterprise collaboration serves as a crucial link connecting university education with industrial demands and is key to enhancing the practicality of courses. However, the traditional course teaching lacks a robust school-enterprise collaboration mechanism, with the main issues including: Firstly, the forms of school-enterprise cooperation are monotonous, mostly involving shallow-level collaborations such as "enterprises providing internship venues" and "occasional lectures by experts", lacking long-term and stable cooperation mechanisms [7]. Secondly, enterprises show low enthusiasm for participating in teaching. Due to a lack of policy support and incentive mechanisms, enterprises are unwilling to invest resources in teaching activities such as curriculum design, textbook compilation, and practical guidance. Thirdly, the talent cultivation objectives of universities and enterprises are not aligned, with universities focusing on theoretical knowledge transmission and enterprises emphasizing practical skill development, resulting in suboptimal collaborative teaching outcomes.

2.4. Single teaching evaluation system fails to measure "dual carbon" literacy

Traditional teaching evaluations primarily rely on "final exam scores + experimental reports", focusing on the mastery of theoretical knowledge and lacking assessments of students' "dual carbon" literacy (such as low-carbon awareness, carbon accounting capabilities, and low-carbon technology application abilities) and practical abilities. Specific manifestations include: Firstly, evaluation indicators are singular, failing to incorporate students' performance in low-carbon-related projects, academic competitions, and corporate internships into the evaluation system [8]. Secondly, the evaluation subjects are singular, mainly involving university teachers, with a lack of participation from corporate experts, making it difficult to objectively reflect students' engineering practical abilities. Thirdly, the evaluation methods are static, lacking process-oriented evaluations, which prevents timely feedback on students' learning issues and affects the continuous improvement of teaching quality.

3. Design of a school-enterprise collaborative teaching reform plan to serve the "dual carbon" strategy

3.1. Reform objectives

Guided by the demands of the "Dual Carbon" strategy and centered on school-enterprise collaboration, the following objectives are to be achieved through curriculum reform:

(1) Knowledge objectives

Enable students to master the properties, applications, and carbon footprint accounting methods of low-carbon building materials, understand industry low-carbon policies and technological trends, and construct a comprehensive knowledge system encompassing "basic theory + low-carbon knowledge + engineering applications";

(2) Competency objectives

Enhance students' experimental innovation capabilities (such as testing the properties of low-carbon materials and designing mix proportions), engineering practice capabilities (such as applying low-carbon materials on-site and controlling quality), and project collaboration capabilities (such as participating in enterprise low-carbon projects);

(3) Quality objectives

Cultivate students' low-carbon awareness, environmental protection philosophy, and social responsibility, enabling them to become high-quality civil engineering talents who meet the demands of the "Dual

Carbon” strategy.

3.2. Reconstruction of the curriculum content system

3.2.1. Optimization of theoretical teaching content

The theoretical teaching content is modularly reconstructed around the “Dual Carbon” strategy, divided into three major modules: “Basic Module”, “Low Carbon Module”, and “Engineering Application Module”. The specific content is as follows (Refer **Table 1**).

Table 1. Optimization of theoretical teaching content

Module name	Core content	Class hour proportion	Industry-education integration method
Foundation module	Composition, properties, and quality control of traditional civil engineering materials (e.g., cement, concrete, steel).	40%	University faculty lead instruction, supplemented with engineering cases by industry experts.
Low-carbon module	Properties and applications of low-carbon building materials (e.g., low-carbon cement, recycled aggregates, bio-based materials). Carbon footprint accounting across the material life cycle (ISO 14067 standard, accounting software application). Industry low-carbon policies (e.g., “Assessment Standard for Green Building”, “Carbon Peaking Action Plan”).	30%	Joint lectures by university and industry; industry experts explain current industrial technology trends.
Engineering application module	Application of low-carbon materials in engineering projects (e.g., low-carbon concrete bridges, green buildings). Case studies of low-carbon technologies (e.g., 3D-printed building materials, application of smart materials). Enterprise low-carbon project practice (e.g., material carbon footprint analysis, low-carbon material selection).	30%	Enterprises provide real-world cases and projects; joint guidance from university and industry.

3.2.2. Innovation in experimental teaching content

The experimental teaching content is transformed from “verification-oriented” to “innovative and comprehensive”, with the addition of experimental projects related to the “Dual Carbon” strategy. See **Figure 1**.

(1) Necessary traditional experiments (such as measuring the water consumption for standard consistency of cement and testing the compressive strength of concrete) are retained to consolidate students’ experimental foundations;

(2) Experimental projects such as “Optimization Experiment on Mix Proportion of Low Carbon Concrete”, “Performance Improvement Experiment on Recycled Aggregate Concrete”, and “Degradation Performance Testing Experiment on Bio-based Materials” are added to guide students in exploring methods for optimizing the performance of low-carbon materials;

(3) A “Material Carbon Footprint Accounting Experiment” is introduced, allowing students to use LCA (Life Cycle Assessment) software (such as Simapro and Ecoinvent) to calculate the full life cycle carbon emissions of materials such as cement and concrete and to write carbon footprint reports.

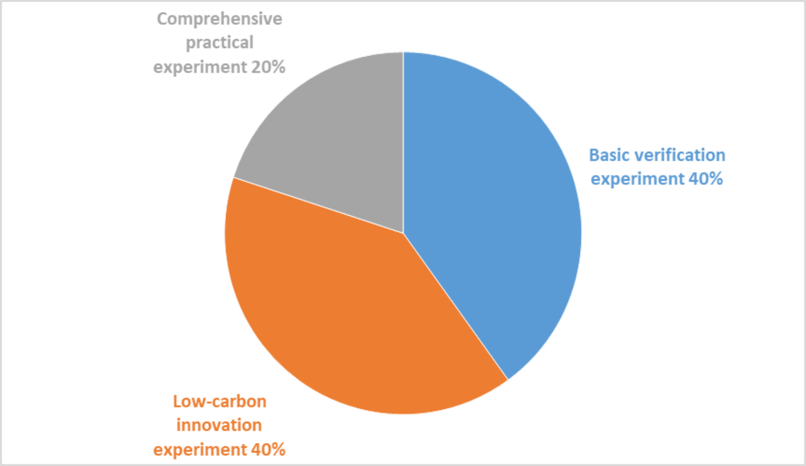

Figure 1. Proportion of innovation in experimental teaching content.

3.2.3. Development of teaching materials and resources

The university and enterprises jointly compiled the teaching material titled "Civil Engineering Materials (Low-Carbon Version)", which highlights the characteristics of "dual carbon" and incorporates real-world enterprise cases (such as China State Construction Engineering Corporation's low-carbon construction projects and China Resources Cement's low-carbon cement production technology) [9]. Simultaneously, an online teaching resource library was established, including: videos of enterprise production lines (e.g., the production process of green building materials), videos from engineering sites (e.g., low-carbon concrete construction), videos of expert lectures (e.g., trends in low-carbon technologies in the industry); typical low-carbon engineering cases from home and abroad (e.g., the application of green building materials in the Shanghai Tower and carbon footprint management in London's The Shard); carbon footprint calculation software, databases for testing the properties of low-carbon materials, and compilations of industry policies and regulations.

3.3. Innovation in university-enterprise collaborative teaching models

3.3.1. "Three-phase" classroom teaching model

The "three-phase" classroom teaching model, which combines lectures by university teachers, special topic lectures by enterprise experts, and student project presentations, is adopted. The specific implementation process is as follows:

(1) Phase 1 (University Lectures)

University teachers explain fundamental theoretical knowledge (such as the basic properties of materials and carbon footprint calculation methods) to lay a theoretical foundation for students;

(2) Phase 2 (Enterprise Lectures)

Enterprise experts, drawing on their project experience, explain the engineering applications of low-carbon materials (such as the use of recycled aggregates in bridge engineering and the production process of low-carbon cement) and share the latest technological developments in the industry (such as solid waste recycling technologies and carbon capture technologies in building material production) [10];

(3) Phase 3 (Project Presentations)

Students, working in groups, conduct project research centered around the theme of "low-carbon material applications" (such as "Optimization Plan for the Concrete Carbon Footprint of a Campus Building") and present their findings to teachers from both the university and enterprises, who then provide joint feedback.

3.3.2. "University-enterprise joint practice" model

Construct a multi-tiered practical teaching system integrating "on-campus experiments, enterprise internships, and project-based practice", which specifically includes:

(1) On-campus experiments: Students complete foundational verification experiments and low-carbon innovation experiments in university laboratories, under the joint guidance of faculty from both universities and enterprises (with enterprise instructors providing engineering feasibility suggestions for experimental plans);

(2) Enterprise internships: Students are arranged to undertake two-week internships at partner enterprises (such as green building material production companies and low-carbon construction firms), participating in material production, quality inspection, construction site management, and other tasks to understand the practical application processes of low-carbon materials;

(3) Project-based practice: Universities and enterprises jointly release "Low-Carbon Material Application Projects" (e.g., "Selection of Low-Carbon Materials for a Residential Area Renovation Project", "Optimization of Concrete Carbon Footprint for a Bridge Project"). Students, in groups, undertake these projects and, under the joint guidance of enterprise mentors and university instructors, complete project design, implementation, and report writing.

3.3.3. "Dual-tutor system" guidance model

Each student participating in project-based practice is assigned a "university instructor + enterprise mentor", forming a dual-tutor guidance model:

(1) University instructors

Responsible for guiding students in theoretical knowledge learning, experimental design, and project theoretical analysis, ensuring that students' research meets course requirements;

(2) Enterprise mentors

Responsible for guiding students in project practical aspects, providing frontline engineering technical support (such as material selection advice, carbon footprint calculation data), and helping students solve problems encountered in practice.

3.4. Construction of university-enterprise collaborative practical teaching platform

3.4.1. University-enterprise joint laboratories

Universities and partner enterprises (such as building material production companies and construction engineering firms) jointly establish a "Joint Laboratory for Low-Carbon Civil Engineering Materials". The laboratory is equipped with low-carbon material performance testing equipment (such as carbon emission detectors, recycled aggregate strength testers), LCA software, etc., and its main functions include:

(1) Experimental teaching

Providing students with venues and equipment for low-carbon innovation experiments and comprehensive practical experiments;

(2) Scientific research collaboration

Schools and enterprises jointly undertake research and development projects on low-carbon materials (such as new types of low-carbon cement and concrete made from solid waste). Students can participate in these projects to enhance their scientific research capabilities.

(3) Technical services

Provide enterprises with services for testing the performance of low-carbon materials and calculating carbon footprints, integrating teaching, research, and services.

3.4.2. Enterprise practical teaching bases

Select representative enterprises within the industry (such as China Construction Science and Industry Group, China Resources Cement Holdings Limited, and China Building Materials Academy) to establish stable practical teaching bases. These bases primarily undertake the following tasks:

(1) Student internships

Provide venues for students to engage in cognitive internships, production internships, and graduation internships, and arrange enterprise technicians to serve as internship instructors.

(2) Case-based teaching: Use corporate low-carbon engineering projects (such as green buildings and low-carbon bridges) as teaching cases, and organize students to visit and learn on-site.

(3) Faculty training

Provide university faculty with opportunities for corporate practice, helping them stay updated on the latest industry technologies and enhance their practical teaching abilities.

3.4.3. Low-carbon project workshops

Establish "Low-Carbon Project Workshops" based on school-enterprise collaboration projects. These workshops are project-driven and organize students to participate in actual low-carbon projects of enterprises. The specific process is as follows:

(1) Project release

Enterprises release projects related to low-carbon materials based on their own needs (such as "Material Carbon Footprint Accounting for a Certain Construction Project" and "Optimization of Low-Carbon Concrete Mix Proportions").

(2) Student team formation

Students form teams based on their interests and professional expertise and submit project proposals.

(3) Project implementation

Under the guidance of dual mentors, students conduct project research, design solutions, perform experimental verification, and write reports.

(4) Project acceptance

Enterprises organize experts to evaluate project outcomes, and outstanding results can be applied in actual corporate projects.

4. Conclusion

By analyzing the deficiencies of traditional civil engineering materials courses in serving the "dual carbon" strategy, this paper proposes and implements a "four-in-one" collaborative teaching reform plan between schools and enterprises, which encompasses "concept guidance–content restructuring–mode innovation–platform support". The following conclusions are drawn:

(1) The restructuring of course content incorporating "dual carbon" elements effectively fill knowledge gaps in traditional courses and helps students construct a knowledge system tailored to industry needs;

(2) The collaborative teaching model of "classroom + enterprise + project" breaks down the barriers between theory and practice, significantly enhancing students' practical abilities and "dual carbon" literacy;
(3) The practical teaching platform jointly built by schools and enterprises provides strong support for the implementation of the reform, achieving a win-win situation for talent cultivation in universities and enterprise development.

Funding

Teaching Reform Project of the College of New Technology, Hubei Engineering University: Teaching Reform and Practice of the Civil Engineering Materials Course under the Background of "Dual Carbon" Goals in the New Era! Project Number: 2024JY03

Disclosure statement

The author declares no conflict of interest.

References

[1] Wang K, Bao X, Liu B, et al., 2025, Research on Carbon Emission Measurement and Reduction Strategies in the Materialization Phase of Civil Engineering Projects for Railway Stations. Building Science, 41(4): 56–65.
[2] Editorial Board of Policy and Practice Reader on Synergistic Enhancement of Pollution Reduction and Carbon Emission Reduction, 2024, Policy and Practice Reader on Synergistic Enhancement of Pollution Reduction and Carbon Emission Reduction. China Environmental Publishing Group.
[3] Zhang D, 2024, Research on Carbon Emission Characteristics and Key Influencing Factors of Ice and Snow Venues under the Background of "Dual Carbon" Goals, thesis, Beijing Jiaotong University.
[4] Lv Q, 2025, "Four-Chain Integration" of Innovation and Entrepreneurship Education in Higher Vocational Colleges in the Era of Artificial Intelligence: Connotation, Challenges, and Implementation Paths. Hubei Open Vocational College Journal, 38(16): 151–153 + 157.
[5] Sun L, 2025, Analysis of Innovation and Application of Fireproof Materials under the Concept of Green Buildings. Home, 2025(12): 51–54.
[6] Tu P, Lai X, 2023, Research on the Standardized Construction of Practical Teaching in the "Situation and Policy" Course in Universities in the New Era. Research on Ideological and Political Education, 2023(1): 143–156.
[7] Zhang Z, 2025, Exploration of the Construction of On-Campus Training Bases in Higher Vocational Colleges under the Background of Industry-Education Integration. Huazhang, 2025(7): 132–134.
[8] Wu H, Ma B, Zhang H, et al., 2025, Research on the Reform of Practical Teaching in Engineering Majors at Local Undergraduate Colleges under the Background of Emerging Engineering. Journal of Science and Education, 2025(24): 68–71.
[9] Wang X, 2022, Chronology of Northwest University. Northwest University Press.
[10] Chen X, 2021, Civil Engineering Materials. Southeast University Press.