Research on Teaching Reform of Engineering Project Management Course Based on Teaching-Research Integration under the Dual Carbon Goals

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Abstract: With the further implementation of the dual carbon strategy, the construction industry is speeding up its low-carbon and green transition, which imposes higher requirements on the low-carbon management capabilities and comprehensive innovative literacy of engineering cost professionals. At present, the course Engineering Project Management is confronted with multiple challenges: fragmented integration of dual-carbon related elements, an inefficient bidirectional transformation mechanism between teaching and research, vague disciplinary characteristics, and the disconnection between competency training and practical industrial needs. To tackle the above problems, this paper takes the integration of teaching and research as the core path and constructs a full closed-loop reform framework encompassing the infiltration of low-carbon concepts, reconstruction of the teaching system, cultivation of practical competencies, and research supported by teaching feedback. Through restructuring three-stage modular teaching content, developing dual-carbon application scenarios oriented toward engineering cost posts, adopting a hierarchically progressive collaborative teaching mode, and establishing a competency-oriented diversified evaluation system, the present study removes the barriers hindering the transformation of cutting-edge low-carbon research achievements into classroom teaching. The research findings can provide references for the low-carbon transformation and teaching-research integrated reform of similar courses within the engineering cost specialty.

Keywords: Dual Carbon Goals; Teaching-Research Integration; Engineering Project Management; Engineering Cost; Teaching Reform

1. Practical Dilemmas in the Teaching of Engineering Project Management under the Dual Carbon Background

As a major carbon-emitting sector in China, the low-carbon transition of the construction industry has emerged as a critical pillar for attaining the Dual Carbon goals. Carbon emission control and cost trade-off throughout the whole life cycle of construction projects are becoming core competency requirements for engineering cost practitioners[1]. As a core course of the engineering cost program, *Engineering Project Management* serves as a key bridge linking engineering technology, management methodologies and cost decision-making. Nevertheless, the existing curriculum system and talent cultivation model can no longer adapt to the demands of industrial transformation and the education requirements of the new era, and are confronted with multiple practical dilemmas that call for urgent resolution[2].

1.1 Outdated Content System: Fragmented Dual Carbon Elements and Inadequate Professional Alignment

The existing curriculum content still takes the control of three traditional objectives — quality, schedule and cost — as its core framework. It barely covers cutting-edge industry topics such as low-carbon construction, carbon emission control and carbon cost accounting. Even when these topics are addressed, they mostly appear as fragmented conceptual introductions, without forming a systematic knowledge system[3]. Meanwhile, the course content generally follows

the generic logic of civil engineering programs, failing to carry out in-depth adaptation in line with the core positioning of the engineering cost program. It neither deeply integrates carbon emission control with core engineering cost business scenarios (including whole life cycle cost accounting, carbon trading mechanisms and carbon tax policies), nor establishes the analytical logic connecting low-carbon technologies, engineering risks and cost-effectiveness. As a result, students struggle to build a cost decision-making mindset under the Dual Carbon context, creating a noticeable gap between course content and professional cultivation objectives[4].

1.2 Fragmented Teaching-Research Mechanism: Two-Way Disconnection between Research and Teaching and Unfulfilled Talent Cultivation Value

At present, course instruction and faculty research generally operate in isolation from each other, resulting in a severe lack of depth and breadth in the integration of teaching and research. On the one hand, faculty research findings in fields such as low-carbon construction, whole-life-cycle carbon costing and engineering carbon emission control have not been effectively transformed into teaching resources. Classroom teaching lacks support from cutting-edge research cases and real-world projects, with content updates lagging behind industrial development, making it difficult for students to access the latest disciplinary advancements[5]. On the other hand, practical problems identified in the teaching process and students' innovative ideas have not been refined back into research directions. Students also lack channels and platforms to participate in research practices, leading to insufficient training in research thinking and innovative competencies[6].

1.3 Misaligned Competency Cultivation: Practical Teaching and Assessment Systems Fail to Support the Implementation of Dual Carbon Literacy

At the level of practical teaching, the existing course training mainly focuses on traditional schedule planning and cost accounting. It lacks real-world business scenarios including low-carbon engineering project control, carbon emission measurement and carbon cost optimization, as well as hands-on training in mainstream industry digital tools such as BIM-based carbon emission accounting[7]. This makes it difficult to effectively cultivate students' practical competence in low-carbon management and control. At the level of the assessment system, course assessment is still dominated by summative theoretical examinations that prioritize the memorization and reproduction of knowledge points. There is a lack of process-oriented assessment of students' low-carbon decision-making competence, comprehensive analytical competence and research innovation competence. Assessment orientation does not match competency requirement for talents under the Dual Carbon context, which makes it difficult to realize the educational goal of promotion of learning and application by assessment.

2. Restructuring of Dual Carbon Knowledge System and Scenario Transformation Oriented by Teaching-Research Integration

To solve these dilemmas mentioned above, we adopt the dual integration of teaching and research as our main approach; restructuring the core knowledge of Engineering Project Management based on integrating research achievements and cutting-edge industry advancements in the Dual Carbon field, promoting the conversion of abstract low-carbon theories into specific engineering cost application scenarios, realizing deep integration between research resources and teaching content, thus establishing a curriculum knowledge system that suits the distinct features of the engineering cost program[8].

2.1 Content Restructuring: Building a Three-Stage Modular System of "Theory-Application-Innovation"

Following the principle of "sufficient foundation, application-focused core, and innovative expansion", the reform breaks the chapter-based logic of traditional courses. Oriented by the competency requirements of engineering cost positions, it integrates faculty research achievements and cutting-edge disciplinary advancements to construct a three-stage modular knowledge system, realizing the organic integration of Dual Carbon content and project management knowledge[9].

The first stage is the basic theory module. It retains the core theoretical framework of *Engineering Project Management*, and

simultaneously embeds core contents including the Dual Carbon strategy and construction industry transformation, fundamentals of carbon emission control throughout the whole project life cycle, and carbon trading and carbon tax policies. Faculty's basic research findings in the field of low-carbon engineering are transformed into accessible knowledge points to replace vague conceptual introductions, helping students build a basic understanding of Dual Carbon and engineering management and lay a solid theoretical foundation[10].

The second stage is the core application module. Centering on the core dimensions of project management, it deeply integrates Dual Carbon control and cost decision-making content: in the schedule management dimension, the focus is on low-carbon construction organization optimization and collaborative control of construction duration and carbon emissions; in the cost management dimension, highlighting professional characteristics, it elaborates on the composition of whole-life-cycle carbon costs, economic evaluation of low-carbon technologies, and the impact of carbon emission trading on engineering cost; in the quality and safety management dimensions, it extends to green construction standards and key points of low-carbon construction control. This module fully incorporates cases from faculty research projects such as low-carbon building cost measurement and engineering carbon emission reduction pathway optimization, transforming research problems into teaching knowledge points and realizing the pedagogical conversion of research resources.

The third stage is the innovation and expansion module. It sets up cutting-edge thematic sessions on Dual Carbon project management, sorts out the latest domestic and international research progress and industry practices, and designs corresponding small-scale research sub-topics, such as "Cost-Benefit Analysis of Low-Carbon Renovation of Old Residential Communities" and "Comparative Study on Carbon Emission and Cost of Prefabricated Buildings". It recruits high-achieving students to participate in faculty research work, realizing the extension of teaching into research.

2.2 Scenario-Driven Strategy: Anchoring Dual Carbon Application Scenarios with Cost Decision-Making as the Core

Grounded in the core competency objectives of the engineering cost program, this reform embeds Dual Carbon management and control knowledge into authentic engineering decision-making scenarios. It facilitates students' transition from "understanding low-carbon concepts" to "making sound low-carbon cost decisions", thereby realizing the transformation from knowledge acquisition to practical competency development.

First, the reform delivers the transformation from low-carbon technical principles to cost risk assessment. When covering topics such as low-carbon construction technologies and low-carbon material application, instruction no longer remains at the level of technical principles, but carries out in-depth analysis integrated with real engineering cases. For instance, when elaborating on low-carbon construction technology for mass concrete, it simultaneously analyzes disparities in carbon emissions, incremental costs, and maintenance costs arising from cracking risks across different temperature control schemes. This guides students to establish the analytical logic of "low-carbon technology – engineering risk – whole-life-cycle cost", and equips them to evaluate the feasibility of low-carbon schemes from an engineering cost perspective.

Second, it achieves the transformation from research projects to practical training scenarios. Authentic research projects completed or ongoing by faculty are pedagogically adapted and converted into course practical training tasks. Taking a public building carbon footprint accounting project as the carrier, for example, students complete the full workflow in groups, including project carbon emission measurement, low-carbon scheme comparison and selection, and cost-benefit analysis. Through simulating research practice, students consolidate theoretical knowledge, master practical methods for low-carbon cost management and control, and cultivate research thinking and problem-solving competencies in the meantime.

3. Design of a Multi-Dimensional Collaborative Teaching Model for Teaching-Research Integration

Adopting a student-centered approach with competency cultivation as the core goal, and centering on the main thread of teaching-research integration, a multi-dimensional collaborative teaching model is constructed from three dimensions: stratified

teaching, technology empowerment, and assessment reform. This model accommodates the learning needs of students with different foundational levels, strengthens the practical application of Dual Carbon knowledge, and realizes the two-way interaction between teaching and research.

3.1 Stratified Progression: Dual-Track Parallel Development of Foundation Consolidation and Research Innovation

In response to differences in students' foundational knowledge and competency needs, a dual-track stratified teaching approach is implemented. It not only ensures every student meets the basic cultivation requirements, but also provides room for top students to pursue research innovation. For the basic track which aims at all students, emphasizing core course knowledge and fundamental competency development. By adopting methods like case-based teaching and situational teaching, explaining Dual Carbon and project management knowledge using concrete daily life and engineering cases, reducing the cognition barrier. Ensuring all students can master the basic method of low-carbon project management and the logic of cost analysis, meeting the basic requirement of professional cultivation. For the advanced track targeting students who have solid foundation and research interest, assigning inquiry-based learning tasks. Centered around the extraction of sub-problem from faculty's research projects, guide students to independently review literature, design scheme and do analysis, completing learning task by group discussion and presenting results. At the same time opening up access to research projects: recruiting outstanding students to join faculty's research team to participate in basic research work (data sorting, case investigation and report writing), enhancing their innovation capacity and professional literacy in real research practice.

3.2 Technology Empowerment: Digital Tools Underpinning the Implementation of Dual Carbon Teaching

Leveraging digital technologies to overcome the challenge of abstract Dual Carbon knowledge and lack of practical training scenarios, enriching teaching forms and improving the intuitiveness and practical effectiveness of instruction. On the one hand introducing BIM technology and carbon emission accounting software into practical training. Using BIM models to visualize the carbon emission distribution of engineering projects, applying professional software to complete carbon emission measurement and cost comparison of various construction schemes. Mastering digital low-carbon management and control tools through hands-on practice according to practical industry demands. Simultaneously employing virtual simulation technology to reproduce authentic scenario of low-carbon construction and green building, overcoming the shortcoming of physical practical training condition. On the other hand, employ problem-driven flipped classroom to promote teaching-research integration. Before class distributing cutting-edge literature, research cases and preliminary research question to students, guiding them to conduct independent preview and initial exploration. In class holding problem-oriented seminar: teacher delivering targeted explanation about core principle and research method, sorting out the logical framework of knowledge. Establishing a complete closed learning loop of "independent exploration before class – in-depth discussion and advancement during class – expansion and extension after class", drive students' transition from passive knowledge reception to active inquiry.

3.3 Evaluation Restructuring: Transition from "Knowledge Assessment" to Comprehensive Evaluation of " Competency + Literacy"

Traditional single assessment model is reformed based on the competency requirement for talents under the Dual Carbon context. Multi-dimensional evaluation system combining process-oriented assessment, summative assessment and goal achievement analysis are built to comprehensively evaluate students' knowledge mastery, competency application and literacy development. Process-oriented assessment accounts for no less than 40% of the total evaluation, covering multiple dimensions including classroom seminar performance, phased practical training outcomes, completion quality of group research projects, and independent learning performance. It tracks students' learning process and competency growth throughout the course. In summative assessment, the proportion of rote

memorization-based questions is greatly reduced, with engineering scenario analysis questions as the main form. Presented with authentic engineering project backgrounds, students are required to complete tasks such as low-carbon scheme comparison and selection, carbon cost accounting, and multi-objective optimization decision-making, so as to comprehensively test their comprehensive application competencies. Meanwhile, a course goal achievement evaluation mechanism is established. Against the three-dimensional course goals of knowledge, competency and literacy, the attainment of each goal is quantitatively analyzed. The evaluation results are fed back to guide the optimization and adjustment of teaching content and methods, and also provide practical basis for refining subsequent research directions, forming a continuous improvement closed loop of "evaluation – feedback – improvement".

4. Practical Outcomes of the Teaching Reform

This teaching reform has been rolled out in two rounds for the *Engineering Project Management* course, covering 3 parallel classes across 2 grades of the engineering cost program at our university, with a total of 132 student participants. A comparison of teaching data, student feedback and competency assessment results before and after the reform shows that the reform has yielded remarkable effects and effectively addressed the core problems facing the current course.

4.1 Construction of a Three-in-One Course Teaching System Integrating "Dual Carbon + Teaching-Research + Engineering Cost"

This reform thoroughly breaks through the limitations of traditional courses: overemphasis on theoretical knowledge with neglect of cutting-edge disciplinary advancements, and priority given to management content with insufficient focus on engineering cost practice. With teaching-research integration as the core bond, it deeply aligns the requirements of the Dual Carbon strategy, cutting-edge disciplinary research, and the distinctive features of the engineering cost program, establishing an integrated teaching system structured as "modularized basic theories – scenario-based core content – research-oriented innovation and expansion". The course content not only aligns with the talent demands of industrial transformation and is underpinned by solid research foundations, but also highlights the core positioning of the engineering cost program, providing a replicable reference framework for the low-carbon reform of similar courses.

4.2 Dual Improvement in Students' Learning Initiative and Comprehensive Competencies

The stratified teaching approach and inquiry-based learning model have fully stimulated students' learning initiative and innovative awareness. Teaching data show that after the reform, student class attendance rate has risen from 89% to 95%, and in-class interaction participation has increased by over 65%. Students have completed a total of 28 group inquiry projects, submitted 132 low-carbon scheme analysis reports, and independently compiled more than 70 engineering cases. Meanwhile, students' performance in academic competitions has improved significantly. Since the implementation of the reform, 11 students have won awards in provincial and university-level engineering cost and engineering management competitions, with low-carbon themed entries accounting for over 40% of all participating projects. Students' comprehensive application competencies and innovation literacy have been effectively fostered.

5. Conclusion

Against the background of China's Dual Carbon Strategy, talent development for engineering cost programs need to actively adapt to the demand of industrial transformation. Integration of teaching and research is the key path to advance curriculum upgrading and improve education quality. Teaching reform of the Engineering Project Management course, taking advantage of its unique characteristics and focusing on two-way integration of teaching and research can solve the problem that exists in the current curriculum (outdated content, disconnection between teaching and research, competency mismatch), and through restructuring the knowledge system, transform theoretical content into practical application scenario, innovate teaching mode and reform assessment mechanism, not only cultivate students' cost management mindset for low-carbon engineering governance, but also provide persistent momentum for continuously optimize the course and deepen academic

research.

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