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Exploration and Practice of Green and Low-Carbon Engineering Education in the Field of Concrete Science in Ethnic Colleges

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Abstract: The teaching reform of the "Concrete Science" course was studied within the context of green and low-carbon engineering education at ethnic colleges. The existing issues were systematically analyzed to propose targeted improvement pathways within the course. There were four core issues in current curriculum teaching: lagging innovation in teaching content, insufficient innovation in teaching methods, shortcomings in teacher literacy, and an urgent need to improve the evaluation system. In response to the issues above, a comprehensive three-dimensional reform approach was proposed, and a three-dimensional knowledge system that integrates "traditional materials, green technology, and industry standards" was established. This system incorporates cutting-edge content, such as mix design for low-carbon concrete and carbon footprint calculations. Leveraging the BIM platform, we conduct comprehensive lifecycle simulations of green concrete engineering and advocate for a teaching methodology that integrates "virtual simulation, engineering case studies, and industry-academia-research collaboration." A cultivation mechanism integrating "enterprise practice, green certification, and teaching and research training" was developed to encourage teachers' involvement in research and development projects of low-carbon building materials, as well as the formulation of industry standards. We establish an "enterprise practice + green certification + teaching and research training" training mechanism. Teachers were encouraged to participate in research and development projects related to low-carbon building materials and the formulation of industry standards. A diversified evaluation system of "knowledge mastery+practical application+innovative thinking" was built, incorporating green design schemes, low-carbon experimental reports, and other assessment indicators. By deeply exploring the compatibility between the courses and the green and low-carbon education goals, we aimed to promote the development of green and low-carbon engineering education in ethnic colleges, improve the teaching quality of the concrete science course, and cultivate professional talents who were in line with the green transformation requirements of the construction industry.

Keywords: Low-carbon engineering education; Knowledge system; Teaching mode; Multi-dimensional evaluation system

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1. Introduction

Green and low-carbon development has become a national strategy, and it is a core issue in the current global context of intensified climate change and resource and environmental constraints. To integrate the concept of green and low-carbon into the curriculum and teaching materials of all educational stages for the general public and to promote the popularization and development of green and low-carbon education in engineering education [1]. In recent years, China has also increased its investment and policy support for green and low-carbon education, as shown in **Figure 1**. Concrete science, as a core course for the inorganic non-metallic materials engineering major, has a direct impact on the teaching content, which in turn affects carbon emission control and resource utilization efficiency in the construction industry. The green transformation plays a crucial role in achieving the "dual carbon" goals. As one of the significant sectors of global carbon emissions, the construction industry[2]. However, the traditional teaching of concrete science mainly focuses on material properties and construction techniques, with insufficient attention paid to the research and development of lo-w-carbon materials, green construction processes, and the management of the entire life cycle carbon footprint. It has led to a structural mismatch between talent cultivation and industry demands [3].

However, traditional teaching of concrete science mainly focuses on material properties and construction techniques. For a low-carbon university that serves as an essential platform for regional economic development and the inheritance of ethnic culture, its engineering education needs to not only strengthen the professional foundation but also highlight the integration of green and low-carbon concepts with the sustainable development of ethnic areas. At the same time, the traditional architectural wisdom of the multi-ethnic areas in the southwest also contains local experience in green construction. In this context, exploring the green and low-carbon transformation path for the concrete science course in engineering education in ethnic colleges is not only a response to national policies but also an inherent demand for promoting the transformation and upgrading of the construction industry in ethnic regions. Taking the core courses of concrete engineering in our university's inorganic non-metallic materials engineering major as an example, in combination with the requirements of green and low-carbon education policies and the development trends of the industry technology, from the four dimensions of teaching content, teaching methods, teacher quality, and evaluation system, this paper discusses how to integrate the concept of low-carbon into them. By analyzing typical cases and teaching practices, the aim is to provide a feasible reform path for national colleges and universities to serve the "carbon neutrality" goal in engineering education.

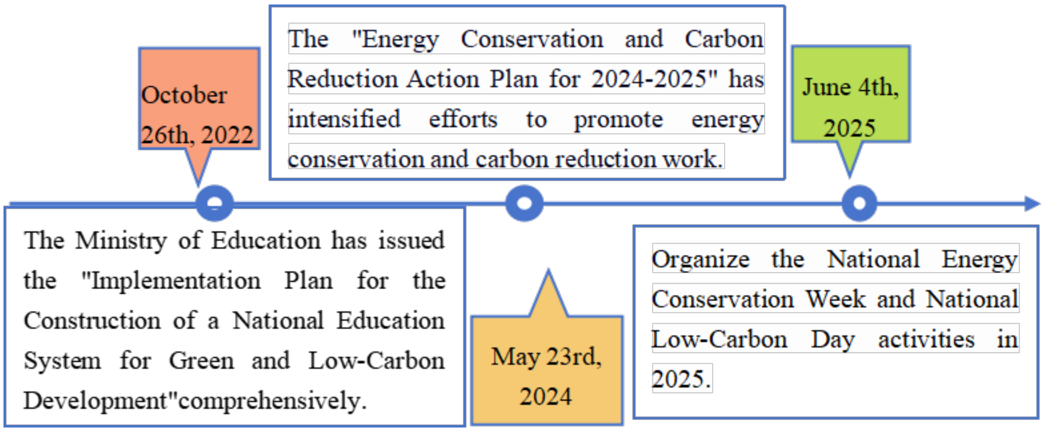

Figure 1. Policies related to green and low-carbon education that have been introduced in China in recent years.

2. The problems existing in the teaching process of the concrete science course in green low-carbon engineering education

2.1. Teaching Content Dimension

The current concrete science course has three teaching shortcomings. Firstly, the knowledge system of green and low-carbon is not complete. The course content still mainly focuses on traditional concrete technology. There is insufficient coverage of green and low-carbon concrete technologies, material recycling, energy conservation, and emission reduction. There is a lack of systematic integration of typical green practice cases, such as the large-scale application of industrial solid waste and geopolymer concrete. Secondly, the update of cutting-edge technologies is lagging. The "four new technologies" in the construction industry —namely, carbon capture and storage, ultra-high pumping, prefabricated and assembled components —have not been timely incorporated into the textbook system. Thirdly, the integration of interdisciplinary knowledge is lacking. The cross-disciplinary content, such as engineering technology and materials science, environmental science, and economics, has not been effectively connected [4]. For instance, cross-disciplinary application scenarios, such as carbon footprint accounting for concrete and photovoltaic concrete, have not yet been integrated into the teaching framework.

2.2. Teaching Method Dimension

Currently, there are two significant shortcomings in the teaching of concrete. Firstly, the teaching mode is rigid. In traditional classrooms, the teacher primarily provides one-way information, with limited interaction and discussion, and students receive knowledge passively. Laboratory experiments continue to focus on conventional performance tests, such as compressive strength. The design of low-carbon performance comparison experiments (such as the impact of admixtures on carbon emissions) is insufficient. Site internships mainly emphasize construction processes. The on-site investigation of green construction technologies (such as energy conservation in mixing stations and control of carbon emissions during transportation) is lacking, which hinders the penetration of green concepts and the cultivation of innovative thinking abilities. Secondly, digitalization and collaborative teaching are lagging. There is no use of BIM technology to simulate the entire carbon emission cycle of concrete or conduct mix ratio optimization experiments through virtual simulation platforms. There are no PBL teaching cases or VR microscopic reaction simulations. Moreover, the collaborative teaching mechanism with environmental protection enterprises and research institutions in the field of low-carbon concrete research and development has not yet been established.

2.3. Teacher Competency Dimension

At present, there are two deficiencies in teachers' teaching. Firstly, there are shortcomings in the knowledge structure. Some teachers lack interdisciplinary knowledge, such as low-carbon materials and carbon footprint calculation. They lack a deep understanding of professional content, such as ISO 14064, and are unable to integrate quantitative analysis. Secondly, there is a lack of engineering practice and a low accumulation of low-carbon cases. They have not participated in related research projects or lack cooperation with enterprises. They are unable to teach based on the engineering low-carbon pain points.

2.4. Evaluation system dimension

There are three issues with the current assessment and evaluation. The assessment content neglects the low-carbon capability. Assignments and exams still mainly focus on traditional knowledge points. There are no quantitative indicators of practical assessment. The scoring criteria do not include low-carbon indicators. There is a lack of incentives for low-carbon innovations. There is no long-term feedback mechanism, and no channels have been established for investigating students' low-carbon awareness or for evaluating enterprises.

3. Four-dimensional improvement measures for integrating green and low-carbon engineering education

3.1. Optimize the course content

To deepen the practice of green and low-carbon engineering education in the concrete science course, it is necessary to restructure the course content system systematically. Firstly, taking the entire life cycle of concrete as the main thread. Integrate knowledge points to construct four modules: "Low-Carbon Material Design - green production - low-carbon service - recycling utilization ." This covers aspects such as the ratio design of alkali-surfaced concrete, the preparation technology of carbon-capturing concrete, the calculation of carbon footprint, and the performance optimization of recycled aggregates. Secondly, a "dynamic update module for low-carbon technologies" is set up. The latest norms, such as the

"Green Building Evaluation Standard" and engineering cases like the zero-carbon buildings in Xiong'an and the offshore concrete for the Hong Kong-Zhuhai-Macao Bridge, are included. Finally, knowledge from environmental science, economics, and computer science is integrated. Through case simulations and data analysis, students are guided to weigh performance, carbon emissions, and technical and economic feasibility, thereby comprehensively enhancing their overall green and low-carbon literacy [5].

3.2. Innovative teaching methods

To optimize teaching methods, efforts can be made in three aspects, shown in **Figure 2**. First, innovate the interactive mode by implementing flipped classrooms and group discussions. Conduct debates and analyses around "The Impact of High Content of Admixtures on Concrete Performance and Carbon Emissions."Add a "Low-Carbon Performance Comparison Experiment" that guides students to design independently in the laboratory class. The on-site internship is combined with the formulation of a green construction inspection checklist by the enterprise and the writing of a research report. Secondly, enhance digital applications. Utilize BIM to build a carbon emission model for the entire life cycle. Employ the virtual simulation platform to simulate mix ratio optimization. Use VR to restore the microscopic reactions of low-carbon materials. Third, establish a collaborative ecosystem. Collaborate with enterprises and research institutions to develop PBL cases. Jointly establish a low-carbon concrete research project. Transform research results into teaching resources. Achieve integration of education, production, and research, and cultivate practical skills for low-carbon practices.

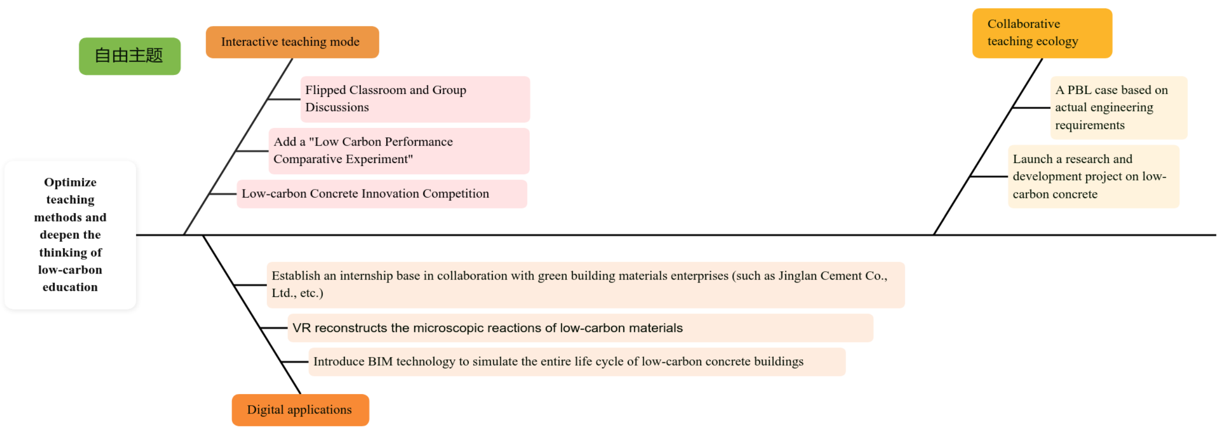

Figure 2. Optimization methods for teaching methods

3.3. Teacher's Practical Experience and the Enhancement of Green Literacy

3.3.1. Measures for Enhancing Teachers' Practical Experience

To enhance teachers' practical experience, four measures can be taken. First, deepen the collaboration between schools and enterprises for education and training. Establish strategic partnerships with leading enterprises in green building materials and environmental protection engineering and jointly build standardized off-campus internship bases. Through agreements on research and development, as well as training program designs, create a practical platform for teachers that is close to the frontlines of the industry. At the same time as assisting enterprises in technological innovation, promote the integration of theory and practice for teachers in scenarios such as green concrete production and low-carbon construction, forming a coordinated development pattern. Secondly, strengthen the drive of research projects. Encourage teachers to apply for research topics related to green and low-carbon. Focus on areas such as concrete materials, construction techniques, and environmental impact assessment. Transform research results into teaching resources to enrich the course content system. Third, increase investment in laboratory construction. Build a specialized experimental platform in the field of green and low-carbon concrete. Through equipment upgrades and space optimization, establish a comprehensive experimental system covering functions such as low-carbon material ratio design, carbon footprint calculation, and durability testing. Provide support for teachers to carry out innovative teaching and research projects. Fourthly, conduct regular training courses. Organize teachers to participate in classes taught by industry experts and enterprise technicians. Systematically study topics such as green and low-carbon concrete technology, construction techniques, and quality control. Comprehensively enhance professional skills and practical operation capabilities.

3.3.2. Measures for Enhancing Teachers' Green Literacy

To deepen the implementation of the green education concept in the concrete science course, four measures can be taken. Firstly, strengthen the promotion of the green education concept during teacher training. Through case studies and group discussions, guide teachers in integrating green and low-carbon concepts into their teaching designs and cultivating students' environmental protection awareness [6]. Secondly, it is necessary to encourage the development of courses related to green concrete, such as green materials and ecological construction techniques, by systematically updating and deeply optimizing the course content, integrating cutting-edge technologies, industry standards, and engineering cases. Enhance students' knowledge and skills in areas such as low-carbon material design and carbon footprint analysis, and strengthen their ability to contribute to achieving the "dual carbon" goals.

Furthermore, the organization participates in academic exchange activities related to green concrete. Through seminars, forums, etc., it interacts with university teachers, research institutions, and enterprise experts to broaden the academic horizons of the teachers. Finally, it advocates that teachers adopt low-carbon behaviors in their teaching, research, and daily life, such as implementing green experimental operations and promoting energy conservation and emission reduction. Teaching and setting a good example guide students in establishing environmental protection awareness and building a green behavior model that integrates knowledge and action.

3.4. Establish a green and low-carbon engineering education evaluation system

This evaluation system should cover dimensions such as teaching content, methods, practical links, student performance, and educational outcomes. It should comprehensively reflect the effectiveness of green and low-carbon engineering education, highlighting the orientation towards environmental protection, energy conservation, and sustainable development. Specifically, it includes: (1) Assessment of teaching content, evaluation of the proportion of green and low-carbon knowledge, integration of educational concepts into teaching materials, and updating of environmental protection teaching resources and technical standards. (2) Evaluation of teaching methods includes assessing the proportion of practical teaching and the degree of green and low-carbon. Focus on the application of methods such as case analysis and project-based learning in low-carbon engineering practice [7]. (3) Evaluation of practical sections: Assess the energy-saving and emission-reduction measures in experiments and training sessions. Students' performance in participating in green projects during enterprise internships and their achievements in environmental protection competitions. (4) Student Performance Assessment: Conduct questionnaire-based assessments to measure improvements in green literacy, monitor daily environmental protection behaviors, and evaluate the effectiveness of low-carbon innovation practices. (5) Educational Outcome Evaluation: Analyze the employment rate of graduates in green-related fields, gather feedback from enterprises and industry associations regarding their professional competencies, and assess the societal impact of research achievements.(6) Teacher Evaluation: Establish a fund for low-carbon teaching innovation, integrate green teaching reforms into performance evaluations, support the development of virtual simulation experiments and low-carbon textbooks, and encourage applications for relevant teaching awards.

4. Conclusions

This study, within the framework of green and low-carbon engineering education in ethnic colleges, examines several critical issues, including the inadequate integration of teaching content with green and low-carbon concepts, insufficient innovation in teaching methodologies, the necessity for enhancing teachers' practical experience and green literacy, and the imperfections in the assessment and evaluation systems. A series of targeted improvement measures are proposed accordingly.

(1) Update and optimize the course content, introduce knowledge related to green and low-carbon materials, environmental protection techniques, etc., and combine with engineering case analyses;

(2) Reform teaching methods, implement the "learning by doing" model, adopt project-driven and flipped classroom approaches, and utilize information technology to enhance teaching effectiveness;

(3) Enhance teachers' practical experience through school-enterprise cooperation and research projects and strengthen training on green education concepts to improve teachers' green literacy;

(4) Develop a comprehensive green and low-carbon engineering education evaluation system that encompasses teaching content, methods, practical sections, student performance, educational outcomes, and teacher assessment, with a strong emphasis on promoting a green and low-carbon orientation.

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Disclosure statement

The author declares no conflict of interest.

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