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Exploration and Practice on the Construction of Postgraduate Curriculum System for Chemical Engineering and Technology under the "Double Carbon" Strategy

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Abstract: The proposal of the "Double Carbon" strategy has put forward new requirements for the cultivation of high-level chemical engineering talents. As a key discipline unit for "Double First-Class" construction in Fujian Province, the College of Chemical Engineering of Huaqiao University is based on the national goals of carbon peak and carbon neutrality, focusing on green transformation and engineering innovation, and has carried out systematic reforms in the construction of postgraduate curriculum systems. This paper analyzes the problems existing in current postgraduate education, such as lagging content update, insufficient interdisciplinary integration, and weak practice platforms, and proposes to construct a "Double Carbon-oriented" multi-dimensional curriculum system with a four-level structure of "foundation-expansion-interdisciplinarity-practice." Through reform measures such as modular curriculum design, project-driven teaching, "1+1" double supervisor mechanism, university-enterprise collaborative education platform, and international joint training mechanism, the concept of "Double Carbon" is promoted throughout the whole process of talent cultivation. Studies have shown that this model has effectively improved postgraduates' academic ability, practical literacy, and green innovation awareness, initially forming a high-level engineering talent training system with the "characteristics of Huaqiao University", and provided a useful reference for the reform of postgraduate education in Chinese universities under the "Double Carbon" background.

Keywords: "Double Carbon" strategy; Chemical engineering and technology; Postgraduate education; Curriculum system; Teaching reform

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1. Introduction

In 2020, China clearly put forward the goals of "carbon peak and carbon neutrality" ("Double Carbon"), leading the direction of high-quality development. This strategy has profoundly changed the energy structure and economic model, and also put forward new requirements for talent cultivation in higher education. As the

key technical force to achieve the "Double Carbon" goal, the cultivation quality of postgraduates in chemical engineering and technology is of great importance. However, the postgraduate curriculum systems of this major in some current universities still have problems such as lagging content update, insufficient interdisciplinary integration, and weak practical support, which restrict the ability to serve national strategies. Responding to the policy calls, such as the Ministry of Education's Work Plan for Strengthening the Construction of Talent Training System for Carbon Peak and Carbon Neutrality, universities are actively exploring a new mechanism oriented by "green development, systematic thinking, and collaborative education." Guided by the "Double Carbon" strategy, this paper focuses on the core contradictions in the cultivation of postgraduates in chemical engineering and technology at Huaqiao University, and explores the curriculum system optimization path based on project traction, disciplinary integration, team collaboration, and whole-process education, aiming to provide practical reference for postgraduate education to serve national strategies [1–2].

2. Research background and research status at home and abroad

2.1. New challenges faced by postgraduate education against the background of the "Double Carbon" strategy

The "Double Carbon" goal is not only an energy reconstruction but also a systematic change in the economy and society, and higher education shoulders the important task of cultivating scientific and technological talents for green transformation. The Ministry of Education of China clearly requires universities to optimize the layout of disciplines and specialties related to carbon neutrality within 3–5 years and build a high-level curriculum system and training platform. As the cornerstone of national innovation, postgraduate education urgently needs to achieve precise docking with the "Double Carbon" strategy through curriculum reconstruction, practice deepening, and value guidance to meet the needs of major national strategies [3].

2.2. Progress in domestic research and practical exploration

Domestic universities have actively responded and optimized the postgraduate curriculum system around the "Double Carbon" goal. The Applied Chemistry major of China University of Petroleum (Beijing) combines industry reality, adds new courses such as "Green Chemistry" and "Energy Engineering Fundamentals", promotes the deep integration of basic courses and carbon neutrality themes, and introduces the OBE concept and project-based learning. Harbin Institute of Technology has proposed the PDGP model (project traction, disciplinary coordination, team collaboration, student participation), built a multi-disciplinary cross-platform of "source-grid-load-storage", and strengthened the comprehensive ability of postgraduates in low-carbon technology, carbon capture, utilization, and storage technology, and other fields. In addition, universities such as Tsinghua University, Southeast University, and Shanghai Jiao Tong University have explored new paths from the perspectives of interdisciplinary integration, industry-education integration, and international cooperation, and initially formed a systematic reform pattern of "national needs-university actions-curriculum system" [4–5].

2.3. Relevant experience of international high-level universities

International high-level universities generally include addressing climate change and promoting carbon neutrality as the core issues of talent cultivation. Representative practices include building interdisciplinary education systems, deepening university-enterprise joint training, and strengthening project-driven practices. For example, the Massachusetts Institute of Technology has established an "Energy and Climate Innovation

Center" to cultivate talents by integrating the three dimensions of basic science, engineering practice, and policy understanding; Germany has funded the construction of multiple "Carbon Neutral Graduate Schools" to promote the deep integration of universities with the government and industry in low-carbon education, cutting-edge technology, and policy research, forming a collaborative innovation and education system for science and technology [6].

2.4. Existing problems and development trends

Although the reform has achieved initial results, the construction of "Double Carbon-oriented" postgraduate curriculum systems in Chinese universities is still facing significant challenges. It is mainly reflected in: lagging update of curriculum content, fragmentation of cutting-edge technical knowledge and traditional courses, difficulty in supporting practical needs; insufficient depth of industry-education integration, low participation of enterprises, restricting the cultivation of engineering practice ability; lack of top-level design and system integration, difficulty in forming a collaborative education system. These problems need to be solved urgently to improve the effectiveness of postgraduate education in serving national strategies [7].

3. Specific paths for curriculum system optimization

3.1. Establishing a characteristic "Double Carbon-oriented" multidimensional curriculum system

Based on the positioning of the "Double First-class" construction backbone discipline in Fujian Province, the College of Chemical Engineering of Huaqiao University takes "project leading, system reconstruction, and platform collaboration" as the core idea, and comprehensively promotes the reconstruction of the "Double Carbon"-oriented postgraduate curriculum system. A four-level modular curriculum system of "basic theory-technical frontiers-interdisciplinary integration-engineering practice" has been constructed: the basic module systematically strengthens core knowledge such as thermodynamics and reaction engineering; the expansion module adds cutting-edge courses such as "Green Process Design", "Carbon Capture and Storage Technology", and "Energy Catalysis" to deepen the understanding of low-carbon technology; the interdisciplinary module integrates environmental engineering, data science, carbon finance and other contents to cultivate systematic thinking and interdisciplinary integration ability; the practice module focuses on typical problems such as carbon emission assessment and green process simulation to carry out project-based training, promote the combination of professional knowledge and social needs, and improve practice and innovation ability. The curriculum setting reflects hierarchical classification: the doctoral stage strengthens the integration of foundation and scientific research, and adds "AI-assisted literature review", "Double Carbon Science and Technology", etc.; the master's stage highlights engineering orientation, and adds "Green Process Flow Modeling", "Smart Experiment Design and Data Processing", etc. At the same time, the "1+1" double supervisor system, stage report system, and international exchange mechanism are promoted to build a characteristic curriculum framework with ability improvement as the core and systematic structure optimization [8–9].

3.2. Promoting the teaching mode of integrating project-driven and outcome-oriented

To meet the needs of postgraduates' high-order capabilities under the "Double Carbon" background, breaking through the traditional teaching and written test mode, a teaching mechanism integrating project-driven and outcome-oriented learning has been constructed. Integrating real scientific research projects, such as the national

key research and development plan and "Double Carbon" special projects, into the whole teaching process, guiding students to carry out project-based learning around practical engineering problems. The teaching process follows the project full-cycle management path of "setting goals-dismantling tasks-constructing solutions-verifying results" to achieve the integration of classroom and scientific research. The assessment method is reformed into a comprehensive evaluation system of "project report-stage report-result assessment", focusing on evaluating ability growth and result quality. This model has effectively improved students' depth of understanding of "Double Carbon" scientific and technological issues, and strengthened comprehensive qualities such as scientific research planning, team collaboration, and project implementation [10–11].

3.3. Constructing an interdisciplinary and collaborative education teaching platform

In order to break down disciplinary barriers and integrate resources, a systematic teaching platform system of internal and external collaboration has been constructed. At the university level, the "Interdisciplinary Teaching Platform for Carbon Neutrality" (such as the Institute of Advanced Carbon Conversion Technology) was established in conjunction with the departments of chemical engineering, materials, environment, etc., to achieve curriculum content sharing, case intercommunication, and teaching collaboration. At the off-campus level, "Carbon Neutrality Industry-Education Integration Practice Bases" were co-constructed with industry-leading enterprises such as Fujian Refining & Chemical Co., Ltd., and Zhangzhou Gulei Petrochemical, developing training courses based on real enterprise problems, and strengthening the application orientation of courses. At the technical support level, virtual simulation platforms such as carbon capture device simulation and green process modeling were developed to break through time and space limitations and improve the dynamic cognition and operational ability of complex systems. This multi-level platform system strongly supports the interdisciplinary integration of curriculum content and the diversification of teaching methods, and is the key guarantee for achieving high-quality "Double Carbon" talent training [12].

4. Main achievements, practice paths, and promotion application value

4.1. Curriculum system reform achievements

Guided by the "Double Carbon" strategy, the College of Chemical Engineering of Huaqiao University has successfully reconstructed the postgraduate curriculum system for chemical engineering and technology. The constructed four-level structure of "basic theory-technical frontiers-interdisciplinary integration-engineering practice" systematically integrates the key direction contents such as green catalysis, energy conversion, carbon capture and resource utilization, environmental policy, and carbon market, significantly broadening the knowledge, vision, and professional breadth of students. Core textbooks integrating the concept of "Double Carbon" have been developed and published, and knowledge maps and case bases have been introduced to enhance the systematicness and timeliness of teaching content. At the same time, a teaching evaluation system with outcome-oriented and ability-oriented as the core has been established, forming a new paradigm of postgraduate teaching of "student-centered, ability-oriented, and result-driven" [13].

4.2. Collaborative education platform and practice path

To strengthen scientific research and engineering practice capabilities, the college has constructed a "teaching-research-industry" trinity collaborative education platform. Through internal collaboration, it has formed interdisciplinary teaching and research platforms for carbon neutrality (such as the Advanced Carbon

Conversion Technology Research Institute) by combining disciplines such as chemistry, materials science, and environmental sciences, achieving resource sharing and joint curriculum development. By integrating external resources, it has established "carbon neutrality industry integration practice bases" and "green process training bases" with leading enterprises in industries such as Fujian Refining & Chemical Co., Ltd, Zhangzhou Gulai Petrochemical, introducing real carbon reduction scenarios from enterprises into engineering training. Using advanced technologies such as AI, virtual simulation platforms, such as carbon capture process simulation and process emission assessment, were developed to improve complex system operation and decision-making capabilities. Relying on national and provincial scientific research platforms and projects, project-oriented teaching is carried out, and through the linkage of "curriculum-platform-project", a practice-oriented whole-process capability training system is established, effectively improving students' engineering literacy, problem-solving, and collaborative innovation capabilities.

4.3. Educational effectiveness and radiation effect

The reform effect is remarkably reflected in the improvement of talent training quality. Relying on the curriculum and project practice, postgraduates have repeatedly won awards in national competitions such as the "China Postgraduate 'Double Carbon' Innovation and Creativity Competition"; graduates with solid professional knowledge and engineering practice ability in the "Double Carbon" field have significantly increased the proportion of employment in national key industries such as carbon neutrality, green energy, and new materials (such as leading enterprises such as CATL and Wanhua Chemical) or further study in well-known domestic and foreign universities, with good development potential. The teacher team has won a number of teaching achievement awards and undertaken a number of provincial teaching reform projects based on the reform practice, and the relevant experience has had a positive demonstration effect in the chemical engineering disciplines of Fujian universities, effectively strengthening the green innovation awareness and national strategic service ability of postgraduates.

4.4. Promotion application value and "Huaqiao University Paradigm"

The core value of the reform in the College of Chemical Engineering, Huaqiao University, lies in the formation of a four-in-one systematic construction path of "institutional system, curriculum content, teaching platform, and international cooperation", namely the "Huaqiao University Paradigm." Its reproducibility is reflected in the following aspects: the "double supervisor system + platform support + outcome orientation" drives students to transform towards proactive research, realizing innovation in the education mechanism. The "university-university cooperation (such as with Xiamen University and the University of Manchester) + university-enterprise collaboration (such as with Hengan Group and Skshu Coatings)" effectively connects the academic chain with the industrial chain, and the joint construction of entities like the "Institute of Advanced Carbon Conversion Technology" promotes achievement transformation. The highly modular and project-based curriculum design adapts to the characteristic training needs of high-level engineering and technological talents. Relying on projects of the China Scholarship Council, doctoral students are supported to exchange at the University of Manchester, the University of Wollongong in Australia, etc. Meanwhile, the construction of bilingual/full English courses is promoted to integrate international cutting-edge concepts and expand the international vision of postgraduates. This model provides a systematic and referable practical solution for the reform of postgraduate curriculum systems in universities under the "Double Carbon" strategy.

5. Conclusion

To serve the national "Double Carbon" strategic goal, it is urgent to build a high-level engineering talent training system for green and low-carbon development. Based on the positioning of Fujian Province's "Double First-Class" discipline, the College of Chemical Engineering of Huaqiao University has systematically promoted postgraduate education reform with the core of "curriculum system reconstruction, platform collaborative construction, and international cooperation deepening", constructed a four-level curriculum system of "foundation-expansion-interdisciplinarity-practice", strengthened the integration of cutting-edge contents and the classified training of academic and professional postgraduates, and relying on the trinity collaborative education platform of "teaching-scientific research-industry", significantly improved the innovation ability and engineering literacy of postgraduates. The expansion of international training has further consolidated the global vision of talent. Practice has shown that this "Double Carbon-oriented" curriculum system has effectively improved the quality of talent training and provided the "Huaqiao University Paradigm" for the reform of engineering postgraduate education under the "Double First-Class" background. In the future, the college will continue to deepen interdisciplinary integration and industry-education collaboration, promote the application and promotion of the reform model, and continue to provide high-level innovative talents for the realization of the national "Double Carbon" goal and the construction of a scientific and technological power.

Disclosure statement

The authors declare no conflict of interest.

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