Construction Model, Strategies, and Effectiveness of Carbon Neutrality Micro-Majors in Double First-Class Universities

Jingnan Zhang [1,a]

[1] School of Elementary Education, Capital Normal University, Beijing 100048, China

[a] 1223101032@cnu.edu.cn

Abstract. Against the backdrop of the growing demand for "dual carbon" talents and the accelerated digital and intelligent transformation, the traditional higher education training system struggles to promptly meet the practical needs of the job market for interdisciplinary and compound talents. As a crucial exploration in the reform of higher education teaching, the micro-major talent training model has emerged and gradually become an important institutional innovation to enhance the adaptability of talent supply and training flexibility. The lag in the supply of emerging interdisciplinary talents, the imbalance of resources between eastern and western regions, and the lack of international practice have become universal practical dilemmas in the development of higher education. Taking Tongji University's "Climate Change and Carbon Neutrality" micro-major as a research case, this paper conducts a systematic analysis focusing on talent training objectives, curriculum system structure, and implementation mechanisms, aiming to summarize its construction logic and operational characteristics. The research finds that Tongji University's micro-major has established an organizational model of "joint training by three universities", implemented industry-education integration with enterprises in Xinjiang and international enterprises, innovatively set up the form of "synchronous classrooms", and promoted industry-education integration through multiple subjects such as enterprises in Xinjiang and international enterprises, forming a collaborative education mechanism. Meanwhile, by innovatively adopting teaching formats such as "synchronous classrooms", it enhances cross-regional curriculum supply capacity and learning experience, thereby providing high-quality talent support for the "dual carbon" field.

Keywords: Carbon Neutrality, Micro-Major, Talent Training Model.

1. Introduction

The urgency of global climate governance issues is driving the structural transformation of higher education to more effectively respond to the country's strategic talent needs, enabling universities to move from a single "knowledge transfer" to active involvement in carbon neutrality governance practices. In September 2020, General Secretary Xi Jinping formally proposed the "dual carbon" goals. The Ministry of Education and the State Council have successively issued a number of policy documents to promote universities to carry out talent training related to carbon neutrality. Overall, carbon neutrality is still an emerging direction in the field of education, and the talent training system is still in its initial stage. There is still a significant gap between the supply capacity and the demand for achieving governance goals.

The "2024 Global Carbon Neutrality Annual Progress Report" shows that as of May 2024, 151 countries around the world have put forward carbon neutrality goals, and "low-carbon development" has become an international consensus. [1] Against this background, international universities generally promote talent training through the project form of "credit-based + industry-university co-construction". The Massachusetts Institute of Technology (MIT) and Stanford University generally adopt a graduate certificate model with 9-12 credits and industry co-construction; Tongji University's carbon neutrality micro-major adopts a 12-credit system and embeds local projects such as Baowu Iron & Steel Group and National Energy Group, forming a rapid response and localized practice path for undergraduate level, which can provide reference for the short-cycle and highly flexible "Thousand Talents Program".

Among China's Double First-Class Universities, Tongji University is one of the earliest universities in China to establish the environmental engineering discipline. It passed the engineering

education certification in 2007 and re-certification in 2013 and 2019 respectively. [2] At the same time, Tongji University is in a leading position in China in many disciplinary directions closely related to carbon neutrality, such as civil engineering, urban and rural planning, and transportation, and has accumulated the foundation and ability for interdisciplinary talent training. Secondly, although many Double First-Class universities also pay attention to carbon neutrality issues, such as Tsinghua University, they mainly focus on undergraduate program construction and have not yet formed a training system based on micro-majors, which is different from the focus of this research. In addition, the configuration of Tongji University's carbon neutrality micro-major is sufficient to benchmark international renowned universities such as MIT, with typical exemplary value. In terms of construction mode, compared with other universities offering carbon neutrality micro-majors such as University of Shanghai for Science and Technology, Tongji University innovatively adopts a cross-regional multi-university collaboration mechanism, providing Tongji's ideas for promoting educational equity. It can be said that in terms of comprehensive strength and innovative models, Tongji University's carbon neutrality micro-major has strong representativeness and research significance among many Double First-Class universities.

Based on this, this research proposes the following research questions:

(1) What are the core elements and structural characteristics of the construction model of carbon neutrality micro-majors in Double First-Class universities?

(2) What typical models (such as cross-regional multi-university collaboration, industry-education integration, etc.) have been formed in the construction of Tongji University's "Climate Change and Carbon Neutrality" micro-major, and what are its key supporting mechanisms and operational processes?

(3) To ensure the effective operation and sustainable development of the micro-major, what construction strategies has Tongji University adopted in terms of enrollment selection, curriculum organization, practice platforms, faculty, and evaluation, and what are its implementation logic and key starting points?

2. Construction Value of Carbon Neutrality Micro-Majors in Double First-Class Universities

The term "micro-major" was first formally proposed by Udacity in 2014, which launched the Nanodegree program in cooperation with Udacity, carrying out short-cycle training for emerging technology fields, mainly for offering micro-majors in emerging technology fields.[3] Micro-majors restructure traditional professional knowledge through curriculum groups to form a "miniature" knowledge system oriented to specific fields, which can realize talent training in a short cycle. [4] With the advancement of practice, micro-majors have expanded from the early "MOOC curriculum groups" to a competency-oriented model of "online carrier + practical links", emphasizing connecting with industry needs with a higher proportion of practice. As a typical emerging interdisciplinary issue in current educational research, carbon neutrality is consistent with the core concept of the micro-major talent training model, providing an adaptive path for "dual carbon" talent training in Double First-Class universities. Between 2015 and 2023, micro-majors were gradually launched and entered the practical stage in some domestic "Double First-Class" universities. However, existing research shows that as of the beginning of 2023, through quantitative analysis of the training programs of 23 domestic universities, only 9 (39%) have clearly listed micro-major modules in the academic affairs system, and the proportion of micro-major projects among all interdisciplinary projects in the university is less than 20%, [5] indicating that the construction of micro-majors is still in the initial stage.

To meet the demand for interdisciplinary and compound talents, Chinese universities have actively provided students with various minor programs and double bachelor's degree teaching plans by leveraging their own high-quality resources or linking with other universities. [6] Up to now, these two types of interdisciplinary talent training models are still the main teaching models, playing an

important role in students' knowledge expansion and interdisciplinary thinking training. However, with the background of the new round of technological revolution, the social requirements for talent training show the following trends: emerging fields are evolving rapidly, and the requirement for practitioners to "keep up with the frontiers" has been significantly enhanced. [7] However, the teaching cycle of previous minor programs and double bachelor's degrees is mostly 2-3 years, and once the training program is set, it is difficult to make flexible changes. This makes it very likely that the knowledge learned by students will be out of touch with cutting-edge technologies when they graduate, and it is difficult to quickly respond to social needs. As a relatively new teaching model, micro-majors aimed at the problem of weak practicality in traditional professional talent training at the beginning of their establishment, [8] taking strong practicality as their core feature distinguishing from other teaching models. In terms of training objectives and curriculum content, they are more inclined to cutting-edge scientific or technical practice fields, and can be flexibly adjusted according to the actual needs of industry frontiers and the labor market. Compared with minor programs and double bachelor's degrees, micro-majors, as the primary level in the minor training system, usually only require 9-25 study hours, and can quickly adjust the curriculum combination according to the industry demand, significantly reducing the risk of "disconnection between production and education".

At present, domestic relevant research on micro-majors mainly focuses on explaining the significance of micro-majors and proposing implementation strategies from the policy level. There is still a lack of in-depth case studies on the specific operation mechanisms and practical effects of carbon neutrality micro-majors. Tongji University's "Climate Change and Carbon Neutrality" micro-major has been running for nearly two years and completed two phases of training, providing a realistic foundation for this paper to analyze the construction process and phased effects. Based on this, this paper will take Tongji University's "Climate Change and Carbon Neutrality" micro-major as a case, focusing on its construction needs, training programs, teaching models, and resource guarantees, analyzing the construction path and development dilemmas of this micro-major, aiming to provide reference experience for the reform of domestic higher education.

3. Analysis of the Construction Model of Tongji University's Carbon Neutrality Micro-Major

3.1. Strategic Background and Demand Analysis

The "Emissions Gap Report 2022" released by the United Nations Environment Programme (UNEP) indicates that the current carbon emissions are still far from the ultimate goal of limiting global warming to 1.5°C. [9] Achieving carbon neutrality is not an easy task, and there is still a large gap in "dual carbon" talents worldwide. Against the background of insufficient supply of "dual carbon" talents, Tongji University launched the micro-major of "Ecological Protection and Green Low-Carbon Development" in 2023, which was renamed "Climate Change and Carbon Neutrality" in the following year to meet the talent training needs in the field of carbon neutrality. At the same time, Tongji University's international cooperation foundation in the field of sustainable development provides support for the construction of this micro-major. In May 2002, UNEP and Tongji University co-founded the "Institute for the Environment and Sustainable Development (IESD)", which serves as an important base for UNEP to carry out sustainable development education, scientific research, training, and exchanges in the Asia-Pacific region. [10]

3.2. Analysis of Training Programs and Curriculum System

3.2.1 Talent Training Objectives

Firstly, cultivating compound talents. Relying on the short-cycle advantage of the micro-major, select cutting-edge knowledge around key carbon neutrality issues, and strengthen the connection between learning content and job capabilities. Different from some related majors that tend to

"emphasize theory over application", [11] Tongji University's "Climate Change and Carbon Neutrality" micro-major implements the teaching objective of integrating "theory + technology", effectively promoting the diversification of teaching content and enhancing students' technical practical capabilities in the field of carbon neutrality. Secondly, emphasizing an international perspective. The training objectives clearly propose to cultivate "leaders in global climate change and carbon neutrality development". Combined with the background of the era of university globalization, Tongji University's International Office clearly points out that it is necessary to comprehensively improve students' international competence, and the first measure is to build a micro-major for international competence training, enabling students to meet the talent needs of international organizations. Thirdly, attaching importance to the shaping of social responsibility. In April 2020, Tongji University promoted the concept of sustainable development by offering elective courses and an interdisciplinary "double tutor" system, aiming to stimulate students' social responsibility for environmental issues. [10] With the development of the carbon neutrality micro-major, its talent training objectives also clearly propose to "shape talents with a high sense of social responsibility". In general, Tongji University attaches great importance to the sense of social responsibility in talent training, and forms a complete education system through the training path of "theory-practice-value output", providing comprehensive support such as theory, experience, and platforms for the talent training objectives of the "Climate Change and Carbon Neutrality" micro-major. [12]

3.2.2 Curriculum Structure

Based on the macro framework of talent training objectives and considering the talent needs of the carbon neutrality market, the core courses of the "Climate Change and Carbon Neutrality" micro-major are determined as 6 courses: "Climate Change and Green Development", "Green Energy and Low-Carbon Technology", "Carbon Trading and Carbon Finance", "Carbon Emission Accounting", "Carbon Capture, Utilization and Storage", and "Smart Low-Carbon Environment Practice". [13] Among them, "Climate Change and Green Development", "Green Energy and Low-Carbon Technology", "Carbon Capture, Utilization and Storage", and "Smart Low-Carbon Environment Practice" belong to the major of Environmental Science and Engineering, while "Carbon Trading and Carbon Finance" and "Carbon Emission Accounting" are interdisciplinary integration courses of Environmental Science and Engineering and Business Administration. The Environmental Science and Engineering major obtained an "A+" rating in the fourth round of subject evaluation, which is a flagship discipline of Tongji University. The Business Administration major also achieved a good result of "B+", which is a strong discipline of Tongji University, providing strong disciplinary resource support for the construction of micro-major courses and realizing the training of interdisciplinary compound talents.

3.3. Analysis of Teaching Models and Resource Guarantees

3.3.1 Teaching Innovation and Characteristics

To respond to the national "3060" dual carbon strategic goals, Tongji University signed the "Cooperation Agreement on Jointly Offering the 'Climate Change and Carbon Neutrality' Micro-Major" with Xinjiang University, implementing joint enrollment, training, and certificate awarding by the two universities starting from 2024. In December 2024, Tongji University, Xinjiang University, and Kashgar University further signed a cooperation agreement, forming a three-university joint training model. In terms of teaching organization, this micro-major adopts cross-university and cross-regional online-offline integrated teaching: teachers give offline lectures in the smart classroom of one university, students from other universities attend the lectures synchronously in smart classrooms, and realize real-time interaction and classroom feedback through online platforms, thereby realizing the complementary of teaching resources between Shanghai and Xinjiang and promoting collaborative education between the eastern and western regions. In terms of resource expansion, this micro-major shares some curriculum resources with non-cooperative universities through a cross-university opening mechanism, and has carried out cross-university opening and resource sharing

with universities in Shanghai such as Fudan University, further expanding the project's radiation scope and demonstration effect.

3.3.2 Resource Guarantees

The "Climate Change and Carbon Neutrality" micro-major is an innovative teaching exploration by Tongji University to promote the transformation of traditional advantageous engineering majors towards "digital intelligence, greenization, and integration", highlighting practical orientation and resource integration capabilities. In terms of practical links, Tongji University has organized teachers and students teams to conduct field visits and technical observations in Xinjiang. For example, the CCUS demonstration device built by National Energy Group Xinjiang Chemical Co., Ltd. captures and stores 100,000 tons of carbon dioxide annually, which can provide typical teaching cases for courses such as "Carbon Capture, Utilization and Storage" and "Carbon Emission Accounting". [14]

In terms of international training, the micro-major provides students with a diverse exchange platform through enterprise visits and transnational cooperation: on the one hand, it organizes students to enter overseas enterprises to carry out practical exchanges on "dual carbon" related processes and management, such as taking GEBERIT Group in Switzerland as the first stop of academic innovation activities; on the other hand, relying on Tongji University's cooperation foundation with universities such as Darmstadt University of Technology in Germany, the University of São Paulo, [15] and Loughborough University [16] in the field of environment and sustainable development, it expands joint practice and learning opportunities, such as exchanging with teachers and students from Darmstadt University of Technology at Shanghai Xinghuo Sino-French Water Supply Co., Ltd. and participating in the "Climate Change and Global Governance" Polar Summer School, providing support for the development of students' international competence. In terms of resource guarantees, Tongji University has clearly taken micro-major construction as the driving force since 2019, providing institutional support at both software and hardware ends. On the software side, it has formulated supporting policies such as funding investment, incentive mechanisms, teaching performance recognition, and workload calculation, improving teachers' participation enthusiasm and strengthening teaching operation guarantees. [17]

3.3.3 Faculty Strength

The "Climate Change and Carbon Neutrality" micro-major has a high-level faculty team, including 20 national-level high-level talents such as academicians of the Chinese Academy of Engineering, Yangtze River Scholars, winners of the National Outstanding Youth Fund, and leading talents of the National "Ten Thousand Talents Program". In terms of improving faculty capabilities, since 2019, Tongji University's Undergraduate School has continuously organized online open course construction and blended teaching seminars, and jointly carried out "online-offline blended golden course" training with Zhihuishu Network, promoting teachers' curriculum construction and teaching method renewal. The university has held the "E9 Alliance, East-West University Curriculum Sharing Alliance 'Online-Offline Blended Golden Course' Seminar", [18] enabling teachers to better improve their teaching capabilities and optimize teaching methods. Cooperative university Xinjiang University promotes cross-university teaching and research and teacher development through platforms such as "virtual teaching and research sections". As of the end of 2024, more than 40 teachers have participated, forming a faculty guarantee for micro-major teaching. At the same time, the two universities have established a joint scientific research mechanism and jointly applied for the autonomous region key project "Evaluation of Carbon Emission Reduction Benefits of Photovoltaic Power Generation and Desertification Control" in 2024, forming a collaborative division of labor of "Tongji's theoretical guidance - Xinjiang's field research", and feeding back teaching and talent training through scientific research collaboration. [19]

4. Construction Effects and Challenges of Carbon Neutrality Micro-Majors in Double First-Class Universities

From a policy perspective, Tongji University's "Climate Change and Carbon Neutrality" micro-major has provided a practical fulcrum for higher education equity and western green transformation through cross-regional collaborative training. In August 2024, the Ministry of Education launched the "MOOC Westward Journey Program 2.0", emphasizing the integration of high-quality resources through digital technology and promoting cross-regional teaching to alleviate the shortage of faculty and resources in western universities. [20] Tongji University, together with Xinjiang University and Kashgar University, has formed a three-university collaborative training model, realizing the cross-regional sharing of high-quality curriculum resources through "synchronous classrooms", MOOCs, etc., and building a collaborative path of "resource sinking - local adaptation". At the same time, the western region is facing the practical demand for green and low-carbon development and energy transformation. [21]

At the micro level, the three-university linked "Climate Change and Carbon Neutrality" micro-major promotes students' ability formation and employment quality improvement through an integrated model of "MOOC + synchronous classroom + enterprise internship". Among them, while retaining the shareable advantage of online courses, the "synchronous classroom" introduces a real-time interaction mechanism, making up for the lack of interaction in traditional online courses, and enhancing learning experience and learning investment through improving two-way communication between teachers and students. [22] However, compared with traditional classrooms, the interactivity of online courses is obviously lacking, and the learning quality of students in online open courses has been questioned. [23] In the interviews with students of this micro-major, some students mentioned that they "like this way very much" and "can communicate with teachers at any time, and one-way output has become two-way communication". [19] This teaching model has enhanced the attractiveness of the classroom and provided reference experience for the quality upgrade of online education.

Although the "synchronous classroom" has alleviated the lack of interaction in online learning to a certain extent, as an initial exploration of three-university cooperation, this micro-major still has room for improvement in curriculum integration and resource coordination, mainly reflected in three aspects. Firstly, the curriculum implementation still partially relies on MOOC self-study, and the learning quality is greatly affected by students' self-discipline. Student interviews also reflect the phenomenon of "watching videos while doing other things", making it difficult to guarantee classroom investment. Secondly, courses are distributed on multiple platforms such as Chaoxing Erya, Zhihuishu, and Xuetangyun, and accounts and data are not interconnected, which increases the learning operation cost and is not conducive to learning progress tracking and phased diagnosis. Thirdly, the transformation of university-enterprise resources is still relatively limited. At present, international enterprise cooperation mostly stays at the level of one-time visits, with insufficient continuous cooperation and in-depth collaboration, leading to a certain tension between the supply of international resources and training objectives.

5. Construction Strategies of Carbon Neutrality Micro-Majors in Double First-Class Universities

5.1. Multi-Dimensional Collaborative Strategies to Improve Online Participation

Based on the problem of reduced student participation caused by online teaching formats, multi-dimensional collaborative strategies are proposed to enhance students' motivation to participate in courses. Firstly, in terms of teaching format, the experiment of "synchronous classroom" has achieved good teacher and student evaluation feedback. The proportion of "synchronous classroom" should be appropriately increased, and some recorded courses should be reduced. "Synchronous classroom" can be prioritized for explaining key and difficult teaching points, and recorded courses can be used for knowledge modules with low learning difficulty to ensure that students firmly grasp the core

professional content. Secondly, set up hierarchical teaching, make full use of the advantages of MOOCs such as saving teaching resources, flexible learning time, and repeatable playback, as supplementary learning resources for students, provide curriculum resources for students with spare capacity, and build a hierarchical learning model. Thirdly, optimize and improve the curriculum evaluation mechanism, increase process evaluation, embed interactive methods such as group cooperation tasks and chapter discussions into the curriculum, and enrich the form of curriculum content. At the same time, appropriately include the completion of interactive tasks into the performance evaluation to increase the external driving force for curriculum participation.

5.2. Unify Curriculum Resource Platforms

According to the ecosystem theory, the new ecology of smart education requires teaching scenarios to provide students with a multi-dimensional and multi-subject interactive platform, so as to promote students' differentiated development of higher-order intelligent literacy. [24] At present, there are many online learning platforms for micro-majors, and the platforms are not interconnected, leading to students spending more time and cost in registering accounts and searching for information. Repeatedly switching platforms also reduces the continuity of learning and adds a lot of "ineffective labor" for students. Based on this, the university can actively try to develop an exclusive learning platform for micro-majors, integrating functions such as curriculum learning, resource storage, and interactive communication, to realize a "one-stop" learning entrance. At the same time, since this micro-major involves three-university cooperation, the teaching information among teachers from different universities can also be centrally managed and released through this platform, facilitating students to receive professional-related information in a timely manner and reducing communication costs.

5.3. Expand Industry-Education Integration Resources

Expanding university-enterprise resources is an inevitable requirement for deepening the "industry-education integration symbiosis" and an important starting point for responding to the reform of the modern vocational education system. Compared with traditional university-enterprise cooperation, industry-education integration emphasizes being oriented to the real needs of enterprises and realizing the effective connection between the curriculum system and industry needs. [25] Tongji University has accumulated a relatively rich international cooperation network in the fields of environment, energy, and sustainable development. On the basis of existing cooperation, it can further develop stable practice and exchange channels for micro-majors, improve students' international competence through methods such as "joint practice - two-way visits - project-based learning", and appropriately expand internship regions and problem scenarios to avoid the limitation of vision caused by excessive concentration of practice scenarios. [26]

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