

Article

Pathways for Integrating the Concept of Carbon Neutrality into the Talent Cultivation Process: A Case Study of Animal Production Programs in Chinese Agricultural Colleges and Universities

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Abstract: The realization of carbon peak and carbon neutrality requires a comprehensive and profound transformation of economic and social systems. It is imperative not only for addressing climate change but also for the transformation and upgrading of various industries. This shift entails transitioning from high energy consumption and pollution to focusing on high-quality development, thereby facilitating the transition to a green and low-carbon economy and ultimately realizing sustainable economic and social progress. As modern agriculture evolves and agricultural modernization advances, there is substantial potential and demand for emission reduction in agricultural sectors and rural areas. Agricultural institutions of tertiary education undertake the crucial responsibility of cultivating talents capable of contributing to carbon neutrality efforts. Consequently, it is essential to integrate the concept of carbon neutrality into undergraduate education to meet the growing need for cultivating a workforce capable of achieving national carbon neutrality goals. In this study, a questionnaire is used to analyze the views and current situation of students majoring in animal production regarding the concept of carbon neutrality, and to explore how to conceptualize a knowledge system of carbon neutrality applicable to animal production programs in agricultural institutions.

Keywords: carbon neutrality; talent development; animal production programs



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1. Introduction

Climate change is a prevailing global crisis that currently affects humankind. Over the last half-century, agricultural production has experienced a remarkable surge in scale, speed, and efficiency due to heightened levels of mechanization. As reported by the Food and Agriculture Organization of the United Nations (FAO), global agricultural output has at least tripled between 1961 and 2011 [1]. Notably, agriculture is the second largest contributor of greenhouse gas emissions, with livestock activities serving as a pivotal source. The livestock sector alone is responsible for approximately 7.1 billion tons (t) of carbon dioxide equivalent (CO₂ eq) of greenhouse gas emissions annually, accounting for 14.5% of total anthropogenic greenhouse gas emissions [2]. Of this total, feed production comprises roughly 3.3 billion t, while direct emissions from animal husbandry comprise about 3.5 billion t [3,4]. Another 200 million t comes from on-farm transportation and processing activities. This means that large-scale livestock production methods and poultry farming and rearing practices pose a serious challenge to environmental protection [5]. Therefore, it is crucial to explore more sustainable and safer livestock production methods to reconcile the contradiction between human material needs and ecological safety. In the contemporary context of high-quality development, it is imperative to broaden the traditional narrow conceptual perception of animal husbandry and consider it from the

perspective of ecological production, comprehensively understanding the interplay among various production components in the animal husbandry industry chain [6–9].

The Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming of 1.5 °C provides a clear elucidation of the concept of carbon neutrality [10]. It refers to the offsetting of anthropogenic CO₂ emissions either directly or indirectly generated within a defined time frame through afforestation, energy saving, emission reduction, and so forth. In a broader sense, it also refers to achieving net-zero emission of all greenhouse gases. The primary strategies for reducing greenhouse gas emissions in the agricultural sector include reducing emissions from farmland systems, livestock systems, secondary resources, and living environments [11,12]. Notably, significant attention should be given to reducing methane emissions in paddy fields, nitrous oxide emissions in drylands, and methane emissions from ruminants [13]. Therefore, the adoption of low-carbon emission practices in animal husbandry is crucial to attaining carbon neutrality, while emphasizing the urgent need for high-quality, sustainable, and low-carbon development in this sector [14,15].

During the General Debate of the 75th session of the United Nations General Assembly in September 2020, President Xi Jinping of China made a commitment to intensify nationally owned contributions, to adopt more vigorous policies and measures, and to endeavor to reach the peak of CO₂ emissions by 2030, ultimately achieving carbon neutrality by 2060 [14]. In light of this, the Ministry of Education of China has promulgated the Action Plan for Carbon Neutral Science and Technology Innovation in Higher Education (the Plan) to provide scientific, technological, and human resource support for China's carbon peaking and carbon neutrality goals. The plan advocates for continuous refinement in carbon-neutral and related fields of study, and aims to enhance talent cultivation quality, optimize the talent training system, and spearhead the establishment of world-class carbon-neutral universities and programs [16]. The primary objective of training professionals in animal production should be to meet the requirements of China's low-carbon livestock transformation. This entails cultivating highly skilled talents with carbon-neutral aspirations and social responsibility, possessing a comprehensive understanding of the fundamental principles and holistic knowledge of low-carbon breeding, and having the innovation ability required for low-carbon practice [8].

In alignment with the Chinese strategic commitment to achieving carbon neutrality, the National Institute of Agricultural Science and Technology Strategy of China Agricultural University organized an expert symposium on “Carbon Peak and Carbon Neutrality Strategy and Countermeasures for Agricultural Development” in July 2021. In January 2022, Qingdao Agricultural University established the Efficient Agricultural Carbon Neutral Research Institute in the middle and lower reaches of the Yellow River. This institute is the first carbon-neutral agricultural research institute among Chinese universities. In June 2022, Huazhong Agricultural University launched an international cooperation plan, “Carbon Neutral Terrestrial Ecosystem Carbon Sequestration, Emission Reduction and Green Agricultural Development”, to cultivate innovative talents. Its objective is to cultivate proficient international researchers and technological specialists in carbon sequestration and emission reduction in terrestrial ecosystems and green agricultural development through a collaborative partnership with the University of Lincoln in New Zealand. In May 2023, South China Agricultural University released the “Implementation Plan for Strengthening the Construction of Talents Training System for Carbon Peak and Carbon Neutrality”, aiming to improve the quality of the university's training for professionals and fulfill the national demand for high-quality development in this field.

These initiatives are the first step in the integration of concepts and technologies of carbon neutrality into the talent cultivation scheme in agricultural colleges and universities. However, its theoretical and technological system has recently been developed, and there is a dearth of well-established carbon neutrality programs and corresponding curriculum in agricultural institutions nationwide. Meanwhile, the existing teaching modes primarily focus on theoretical knowledge and outdated case studies, which fails to align with the

social reality in the context of the “dual-carbon” era. Consequently, it is difficult to stimulate students’ learning motivation through classroom teaching, nor can it promote their practical application of learned concepts. In addition, achieving carbon neutrality requires joint efforts in various fields, including energy conservation and emission reduction in industry, carbon sequestration and sinks in natural systems, monitoring and accounting of greenhouse gas emissions, economic and regulatory policy support, and promoting the concept of a green and low-carbon lifestyle. These endeavors render programs of agricultural institutions closely pertinent to carbon neutrality. However, the exploration of how specific programs incorporate carbon neutrality concepts and knowledge into their talent cultivation process to meet new requirements set by the national dual-carbon goal for higher agricultural education needs to be conducted in conjunction with the original professional characteristics of the relevant pathway [8].

In this study, a questionnaire survey was conducted among college students majoring in animal production. The collected data were analyzed and then a comprehensive theoretical evaluation was carried out to integrate the concept of carbon neutrality into the training process of animal production professionals.

2. Materials and Methods

2.1. Materials

The main data for this study were obtained from a questionnaire survey of students majoring in animal production in Chinese agricultural universities. A total of 120 students participated in the survey, representing eight different subordinate majors. The survey used an online method because students came from different provinces.

The questionnaire consisted of two parts. The first part gathered statistical characteristics of students’ personal information, including gender, major, and degree. The second part presented questions in the form of the Likert scale (Likertscale), where participants rated their agreement. The scoring system of the Likert scale (Likertscale) ranged from strong agreement (5 points) to strong disagreement (1 point). For analysis purposes, the Likert scale aimed to highlight the research objectives.

2.2. Methods

The collected data were analyzed by descriptive statistics, and validity and reliability analysis.

3. Results

The socio-demographic findings of this study are presented below.

Of the 120 participants, 45% were men and 55% were women, while 43.33% of participants were from urban areas and 55.83% were from rural areas.

Animal science was the major surveyed the most, accounting for 50% of the participants. Economic zoology and veterinary public health followed, accounting for 11.67% and 8.33%, respectively. The remaining majors had lower proportions: sericulture (10%), apiculture (2.5%), equine science (2.5%), feed engineering (7.5%), and intelligent animal husbandry science and engineering (7.5%).

Reliability analysis was conducted to assess the reliability and accuracy of quantitative data, particularly for attitude scale questions. And the α coefficient between 0.6 and 0.7 indicates acceptable reliability (Table 1).

The KMO value of the questionnaire between 0.7 and 0.8 means the suitability for information extraction. The validity analysis, including Bartlett’s test (the corresponding p value < 0.05), confirmed this survey’s appropriateness (Table 2).

Table 1. Cronbach reliability analysis.

Questions	Correction Item Total Correlation (CITC)	Alpha Coefficient of Deleted Item	Cronbach α Coefficient
Are you willing to learn about “carbon neutrality” and “carbon peak”?	0.698	0.458	0.634
Do you think students majoring in animal production should master the knowledge of “carbon neutrality” and “carbon peak”?	0.560	0.518	
Are you willing to promote the concept of “carbon neutrality” and “carbon peak” with your relatives and friends?	0.465	0.539	
Do you prefer to integrate practical teaching into daily professional courses?	0.243	0.645	
How much do you know about the current “carbon neutrality” and “carbon peak” strategy in China?	0.181	0.724	

Table 2. KMO and Bartlett’s test.

Kaiser–Meyer–Olkin Measure of Sampling Adequacy		0.712
Bartlett’s Test of Sphericity	Approx. Chi-Square	139.788
	df	6
	p	0.000

In this survey, more than half of the respondents (51.67%) stated that they were aware of or understood the current strategy of “carbon neutrality” and “carbon peak” in China. Among them, 25.83% claimed to have a very good understanding, while 11.67% did not understand, 17.5% had little understanding, and 23% considered their knowledge average. These results demonstrate that the majority of respondents possessed a certain understanding of China’s carbon neutrality and carbon peaking strategy.

More than 80% of the students majoring in animal production agreed or strongly agreed that they should acquire the knowledge of “carbon neutrality” and “carbon peak”. In fact, 47.5% of them strongly agreed. Only 2.5% disagreed, indicating that most students believe that this knowledge is highly significant for their professional development and future career planning.

As for activities that could be integrated into professional courses to improve students’ awareness of “carbon neutrality” and “carbon peak”, a significant proportion of the data (84.17% and 85.83%, respectively) favored options such as visiting internship to agriculture-related enterprises and engaging in interesting activities or competitions related to carbon neutrality. This reveals that on-site visits and participation in interesting activities can provide students with a more intuitive and vivid understanding of carbon neutrality, thus enhancing their awareness (Table 3, Figure 1).

Table 3. Results of frequency analysis.

Name	Option	Frequency	Percentage (%)	Cumulative Percentage (%)
Do you prefer to integrate practical teaching into daily professional courses?	Not filled in	1	0.83	0.83
	1	1	0.83	1.67
	2	1	0.83	2.50
	3	14	11.67	14.17
	4	43	35.83	50.00
	5	60	50.00	100.00

Table 3. Cont.

Name	Option	Frequency	Percentage (%)	Cumulative Percentage (%)
How much do you know about China's current "carbon neutrality" and "carbon peak" strategy?	1	14	11.67	11.67
	2	21	17.50	29.17
	3	23	19.17	48.33
	4	31	25.83	74.17
	5	31	25.83	100.00
Are you willing to learn about "carbon neutralization" and "carbon peak"?	1	4	3.33	3.33
	2	15	12.50	15.83
	3	46	38.33	54.17
	4	55	45.83	100.00
Do you think students majoring in animal production should master the knowledge of "carbon neutrality" and "carbon peak"?	1	3	2.50	2.50
	2	17	14.17	16.67
	3	43	35.83	52.50
	4	57	47.50	100.00
Total		120	100.0	100.0

Options 1–5 indicate that the degree increases with the increase in number.

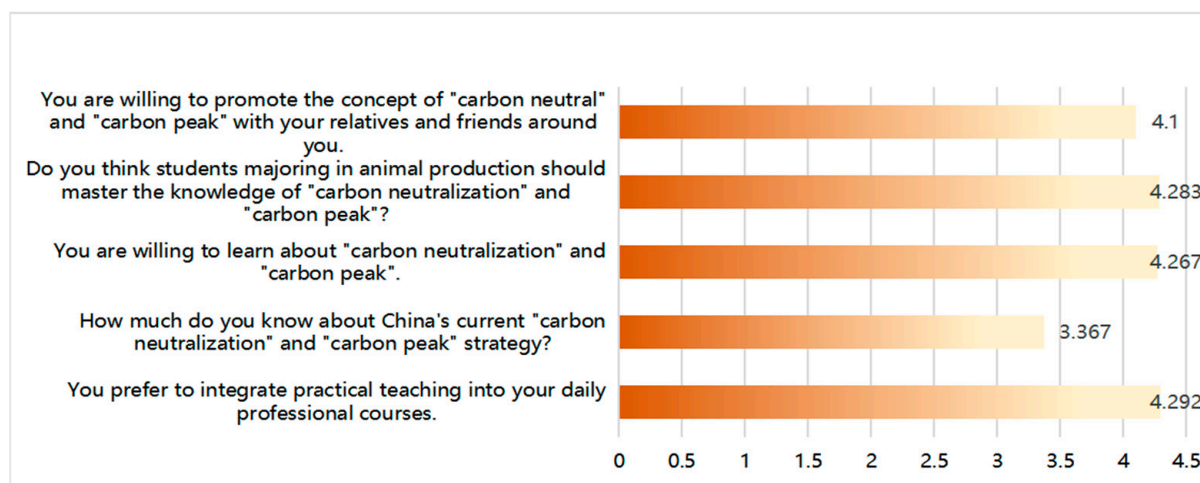


Figure 1. Average value of Likert scale for related questions (the highest score is 5).

4. Discussion and Conclusions

4.1. Opportunities and Challenges

Under the goal of carbon neutrality, the reform and development of animal production specialties should align with the country's main development strategies to ensure the seamless combination of personnel training and social needs. It is of great significance to incorporate the concept of carbon neutrality into undergraduate programs in animal science. A comparative analysis was conducted using data from China's National Statistical Yearbook and inventory data to assess the greenhouse gas emission intensities associated with various stages of livestock production from 2005 to 2014 (Figure 2). The findings indicate a gradual downward trend in the emission intensity for beef, milk, and poultry products (meat and eggs), a generally stable emission intensity for pork, and a slow increase in the emission intensity for mutton. The production stage contributes the most to emissions, with lamb, beef, pork, milk, and poultry products (meat and eggs) being the primary contributors. Notably, lamb and beef have significantly higher emissions compared to other products, ranging from 12 to 33 times higher. Therefore, it is plausible to reduce greenhouse gas emissions by increasing animal productivity, downsizing breeding or shortening the breeding cycle. At the same time, optimizing the dietary composition of animal-based foods and increasing the proportion of milk and poultry can also contribute to the reduction of greenhouse gas emissions. To achieve carbon reduction and environmentally sustainable development in livestock production, it is necessary to strengthen the concept of carbon

neutrality in talent cultivation. Additionally, reforming the professional teaching system, curriculum, international exchange and cooperation, and practical education are also indispensable [17].

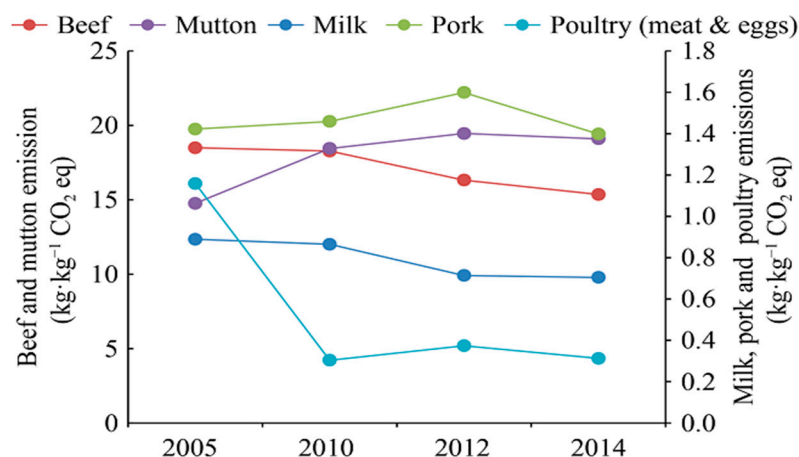


Figure 2. Greenhouse gas emissions from different livestock species between 2005 and 2014 [17].

However, China's livestock industry is lagging behind developed nations in terms of emission reduction, carbon sequestration technology, and professionals and research infrastructure dedicated to this field. The current technical resources for developing low-carbon agriculture, such as detection technology, emission reduction technology, and fine management technology for emission sources, remain inadequate. Moreover, the training objectives of animal production programs at selected agricultural institutions generally emphasize cultivating highly skilled individuals proficient in production management, basic skills, and innovation, but there is a noticeable absence of education regarding carbon neutrality.

The inclusion of carbon neutrality in the animal production curriculum is still in its infancy stage, and there are no established comprehensive programs in place. In addition, the teaching curriculum system lacks mature, comprehensive, and practical design ideas [18]. In this research, it has become evident that the course assessment mechanism restricts most students in primarily acquiring theoretical knowledge in professional courses, preventing them from establishing a strong correlation between the acquired knowledge and the current carbon situation, national development, and strategic policies for in-depth analysis and comprehension. While some teachers have attempted to integrate carbon neutrality knowledge into their teaching, this integration is still at a preliminary stage [19].

For instance, Livestock Environmental Hygiene course is an essential part of the animal production programs and animal science specialty, particularly in relation to dual-carbon objectives. It covers both basic theories and applied technologies. The basic theories include animal adaptation and stress, characteristics of natural environmental elements (heat, light, air, sound, water, soil, etc.) and their interaction with livestock, hygiene requirements, and preventive countermeasures for optimizing the utilization of beneficial environmental factors and for mitigating the impact of detrimental environmental factors. The applied technologies cover livestock production processes, improvement and regulation of the environment in livestock farms and barns, and the implementation of environmental protection measures. A comprehensive understanding of key technologies pertaining to ranch site selection, site planning and building layout, barn cold and heat protection design, barn ventilation, lighting, water supply and drainage design, and barn internal process layout is crucial for comprehending the ranch site and barn environmental control. However, the teaching of carbon neutrality is currently limited to specific chapters, such as the treatment of manure in the livestock farm environment, hindering a holistic understanding of carbon neutrality for students. Given the pressing imperative to achieve the dual-carbon objective, it is recommended that low-carbon concepts and pollution control technologies should be

systematically integrated into the curriculum. Moreover, students should be encouraged to think about pollution control from a low-carbon perspective and establish connections between carbon neutrality and waste control in livestock and poultry production.

4.2. Approaches

4.2.1. Drawing on International Experiences

Developed economies in Europe and the United States have explored training dual-carbon talent, resulting in the establishment of a comprehensive model and system for cultivating such professionals [20]. This system prioritizes competence cultivation, utilizes interdisciplinary intersections, and emphasizes practical skills. It is predicted that in the next decade, 2.8 million new low-carbon jobs will be created [21]. The United Kingdom, for example, has prioritized the realization of a low-carbon economy as its primary energy strategy goal, and has incentivized graduates in STEM fields (science, technology, engineering, and mathematics) to work in low-carbon industries. The University of Edinburgh engages in cross-disciplinary research aligned with low-carbon transition policies, offering both theoretical courses (e.g., carbon financial development and carbon trading) and practical courses (e.g., emission reduction project development and carbon baseline determination) to enhance students' professionalism and practical capabilities. The German Federal Ministry of Education and Research has supported the German Energy Research Programme, specifically in areas of education, human resource development, and research associated with low carbon [22].

Some countries, such as the United Kingdom, Australia, India, and South Africa, have established unified dual-carbon qualification mechanisms. These countries have introduced carbon-neutral national vocational education frameworks and national qualification frameworks for independent assessment of teaching and learning by a third party. Additionally, the American Accreditation Association grants certificates for internationally registered carbon traders, carbon auditors, and carbon asset managers [23]. Internationally recognized qualifications such as Green Sustainable Finance certification from the Chartered Institute of Bankers are accepted. At the employment level, efforts are being made to enhance the competitiveness of carbon-neutral industries to create more job opportunities [24]. The United Kingdom has introduced a green skills package that includes avenues for acquiring green job skills, improving access to carbon-neutral employment, enhancing the quality of counselling and guidance on dual-carbon careers, and providing information regarding the requisite carbon-neutral skills for the forthcoming era [25].

4.2.2. Adjusting Talent Cultivation Objectives

According to the guidelines outlined in the Action Plan for Carbon Neutral and Science and Technology Innovation in Chinese Higher Education Institutions, agricultural universities are required to modify and enhance the existing curriculum for animal production programs [26]. Specifically, it is imperative to seamlessly integrate the concept and practice of carbon neutrality into comprehensive teaching activities at the undergraduate level. Moreover, diligent efforts should be made to cultivate a cohort of exceptional individuals with a holistic understanding of carbon neutrality and the capabilities to effectively reduce carbon emissions and promote carbon sequestration in animal husbandry [19].

These professionals should possess dual-carbon skills in key positions in animal production, such as carbon monitoring, trading, and utilization, to adequately fulfill future needs and directions of the national agricultural and animal husbandry industries towards achieving "carbon neutral" development. In addition, the agricultural universities should foster deeper cooperation with industry and academia to collaboratively establish scientifically sound and practical training programs for agricultural and animal husbandry enterprises. This collaborative approach can explore an innovative training mode characterized by distinct features for animal production programs.

4.2.3. Reforming the Teaching System

Agricultural colleges and universities should adhere to the principle of multi-dimensional goals and subject coordination. Considering their own organizational structure and the distribution characteristics of existing disciplines, they should offer carbon neutrality general education courses through mechanism design, policy guidance, and organizational training. By integrating the concept and practice of carbon neutrality into the curriculum, these institutions can jointly cultivate high-level carbon neutral research and innovative talents across various fields and industries. Course instructions can be divided into two categories: theoretical lectures conducted within a traditional classroom setting and practical teaching methods centered around low-carbon practices. The latter may include visits to industry-representative enterprises or guest lectures delivered by entrepreneurs. Meanwhile, it is essential to revise the existing undergraduate professional training programs and curriculum quality standards to integrate the concept and knowledge of carbon neutrality into the current curriculum system, thereby deepening students' comprehension of professional courses and broaden their knowledge. This process must address two primary concerns. First, a macro perspective is crucial to establish a carbon neutrality knowledge system for animal science programs and assess the applicability of basic knowledge modules to the relevant courses. Second, a micro perspective is necessary to determine the carbon neutrality knowledge that should be included in the relevant courses and subsequently modify the course syllabus for seamless integration of this knowledge.

4.2.4. Enriching Curricular Tools

The inclusion of carbon neutrality knowledge is essential in developing animal production curricula. Foremost, it is advisable to integrate traditional pedagogical approaches with diverse teaching methods, thereby implementing a blended instructional model that aligns with the learning patterns and behaviors of contemporary college students. Practical training simulations, theme seminars, course practice sessions, and teaching techniques such as process demonstration simulation, knowledge transfer scenario, and course practice synthesis can be employed to enhance students' enthusiasm and active engagement in learning process to cater to their diverse needs [22]. This approach has the potential to transform the traditional mode of instruction where teachers impart textbook knowledge and students passively receive it. Instead, it can foster students' critical thinking, innovative spirit, and the concept of carbon neutrality, improving their ability to identify, analyze, and solve problems from multiple perspectives. In addition, problem-oriented teaching can broaden students' knowledge sphere, deepen their understanding, and establish a tangible connection between the acquired knowledge and real-life situations. This will ultimately stimulate their enthusiasm for learning, laying a foundation for their future academic pursuits and professional endeavors.

For example, in the course, Bovine Production, students can be guided to explore strategies and techniques to reduce carbon emissions. Generally, a cow can emit up to 500 liters of methane on a daily basis. For large-scale dairy farms, CO₂ emissions can be reduced through implementing "reduction" measures, such as optimizing feed formulas and adding feed additives to reduce CO₂ and CH₄ emissions from cows. Furthermore, carbon reduction in the production process can be achieved through "recycling" practices, wherein the harmful gases emitted by cows are captured and recycled, and cattle manure is centrally treated through processes like biogas fermentation, thereby reducing carbon emissions associated with bovine activities. Third, carbon reduction in CO₂ emissions can be achieved through "rejection" measures, for example, eliminating breeding facilities that are small in scale, consume high energy, and produce high emissions.

4.2.5. Integrating Theory with Practice

In the context of the dual-carbon target, it is critical for animal production programs to promptly optimize and flexibly adjust their traditional practical teaching content in accordance with the actual situation. Furthermore, they should build innovative plat-

forms for disciplinary competitions centered around the principle of “promoting practical skills through competition”. This approach will leverage the advantages and distinctive characteristics of subject competitions, thereby constantly improving students’ learning experience, facilitating a deeper retention of knowledge, and enabling the application of acquired theoretical knowledge and technical skills in practical settings. This will ultimately contribute to the development of a comprehensive knowledge framework.

Practical teaching extends and expands conventional classroom teaching, capitalizing on the advantages of practical activities and engaging students in the learning process [27]. Field trips, internships, and other experiential learning opportunities allow students to deepen their comprehension and proficiency. Concurrently, practical teaching sessions enable students to apply acquired knowledge and skills to real-world situations, enhancing their interest in learning and improving their academic performance [28].

To enhance practical teaching and learning, we propose an undergraduate practical activity called “Carbon Neutral Plus”. This activity involves comprehensive internships at various establishments, such as livestock farms, feed mills, animal product processing plants, local ecological and environmental departments, environmental assessment centers, sewage treatment plants, and solid waste treatment centers. These internships will provide students with exposure to a range of technologies closely related to the dual-carbon goal, such as carbon emissions monitoring, satellite remote sensing, ground-based observations, and carbon capture, utilization, and sequestration [29].

In addition, we will place a strong emphasis on the discipline competition, “Energy Saving and Emission Reduction”, and actively encourage students to participate in the “National University Students’ Energy Saving and Emission Reduction Social Practice and Science and Technology Competition”. The primary objective is to cultivate students’ awareness of energy conservation and emission reduction while integrating the concept of carbon neutrality. Through a rich variety of practical teaching sessions and disciplinary competitions, our aim is to foster a comprehensive understanding of the dual-carbon goal and facilitate the application of knowledge in practical work, thus contributing to the realization of a green development strategy.

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