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Research on Teaching Innovation of "Environment and Development" in PEP Senior High School Geography Compulsory Volume 2 Based on "Double Carbon" Education

Yongyan Zhu[a], Jiaxin Zhang[b], Yuzhi Dong[c,*]

College of Geography and Ocean Sciences, Yanbian University, Yanji, 133000, China
[a]0000008749@ybu.edu.cn, [b]3213930631@qq.com, [c]yzdong@ybu.edu.cn
**Corresponding author*

Abstract: *In response to the urgent demand for talent cultivation under the national "Double Carbon" strategy, this study addresses three key shortcomings in current senior high school geography teaching: the fragmented "Double Carbon" content in textbooks, overemphasis on knowledge transmission over practice, which leads to weak student initiative, and the insufficient timeliness of teaching resources. Focusing on the "Environment and Development" chapter in PEP Compulsory Volume 2, this research conducts teaching reform through innovating teaching content, improving teaching methods, and expanding teaching resources. Practice shows that students' depth of understanding and application ability of "Double Carbon" knowledge have significantly improved, effectively solving the problems of inadequate textbook integration and lack of initiative. This model provides a replicable path for implementing "Double Carbon" education in geography and has practical significance for cultivating talents possessing ecological civilization literacy in the new era.*

Keywords: *"Double Carbon" Education; Environment and Development; Teaching Innovation; Problem-Based Teaching*

1. Introduction

Global climate change has become a major issue of concern for the international community in the 21st century. To address global climate change and fulfill its responsibilities as a major country, China formally proposed the strategic goals of achieving "carbon peak" by 2030 and "carbon neutrality" by 2060 at the 75th United Nations General Assembly. "Carbon peak" and "carbon neutrality" are collectively referred to as the "Double Carbon" goals. The integration of "Double Carbon" content into subject teaching is an important way to enhance students' understanding of this strategic goal. [1]

The "Environment and Development" chapter in PEP Senior High School Geography Compulsory Volume 2 contains numerous knowledge points related to "Double Carbon", which provides a good opportunity for carrying out "Double Carbon" education. Therefore, this study aims to: 1. Fill the gap in teaching integration: Although current textbooks involve content such as global warming and sustainable development, they have not systematically established connections with the "Double Carbon" goals; 2. To respond to national strategic requirements: The "Double Carbon" goals are the core task of China's ecological civilization construction, and geography education is a key path to popularize the "Double Carbon" concept. Through teaching innovation, students can be guided to understand practical strategies such as industrial structure adjustment and green technology application, and cultivate the ability to integrate knowledge and action to support national strategies; 3. To break the bottleneck of talent cultivation: Traditional teaching focuses on knowledge transmission, and students lack initiative regarding "Double Carbon" initiative. It is necessary to enable students to transform theories into low-carbon life decisions and community actions through problem-driven and situational practice methods, cultivating future citizens with a sense of responsibility.

Innovating the teaching of this chapter based on "Double Carbon" education helps students understand the "Double Carbon" goals, cultivates their ability to use geographical knowledge to solve practical problems and fosters responsible and proactive individuals for achieving the "Double Carbon" goals. [2]

ISSN 2522-6398 Vol. 8, Issue 8: 61-68, DOI: 10.25236/FER.2025.080811

2. Innovation in Teaching Content of "Double Carbon" Education and "Environment and Development" Chapter

2.1 Mutual Promotion and Progress

The "Environment and Development" chapter in PEP Compulsory Volume 2 provides a naturally compatible knowledge framework for "Double Carbon" education, while the integration of "Double Carbon" goals significantly deepens the core concept of this chapter. As core measures to address global climate change and promote sustainable development, the "Double Carbon" goals (carbon peak and carbon neutrality) are highly consistent with the concept of dynamic balance between economic development and environmental protection advocated in the "Environment and Development" chapter, and provide clear and quantifiable indicators and action directions for achieving sustainable development. These measures can effectively mitigate global warming, protect the ecological environment, and promote sustainable development of human society.

2.2 Internal Connection of Knowledge System

The systematic elaboration on global warming in the "Major Environmental Problems Faced by Humans" section of the chapter lays the foundation for students to understand the necessity of the "Double Carbon" goals. It not only points out that excessive carbon emissions are the main cause of global warming but also reveals the direct connection between carbon emissions and human living space through specific phenomena. This echoes the conclusion in the IPCC report that "there is a positive correlation between carbon emissions and temperature rise", providing empirical support for the urgency of the "Double Carbon" goals. The section "Towards Man-Earth Coordination—Sustainable Development" constructs the "Double Carbon" practice path from multiple dimensions.

This enables students to build a complete knowledge system through learning: from "problem cognition" to "cause analysis" and then to "solution path", forming closed-loop logic. By understanding the role of emission reduction, students can visualize the key value of "Double Carbon" goals in coordinating environment and development. Furthermore, when recognizing that excessive carbon emissions threaten the survival of coastal cities through sea-level rise, they can more deeply realize that the "Double Carbon" goals are not only a national strategy but also a survival plan for the future of mankind. This cognition enables the deep integration of "Double Carbon" knowledge with the core literacy of geography.

3. Strategies for Teaching Innovation Integrating "Double Carbon" Education

3.1 Innovation in Teaching Content

3.1.1 Exploring "Double Carbon" Elements in Textbooks

Teachers should deeply explore the "Double Carbon" education elements in the "Environment and Development" chapter of PEP Senior High School Geography Compulsory Volume 2 and build a close connection between textbook content and "Double Carbon" goals. [3] In teaching "Factors of Industrial Location", teachers should guide students to focus on the differences in carbon emissions among different industries. By comparing their energy consumption and environmental impacts, and combining this with the concept of "green economy" in "Towards Man-Earth Coordination---Sustainable Development", students can understand the core value of transforming the industrial structure from "high-carbon" to "low-carbon" for achieving the "Double Carbon" goals. In the section "Transportation Layout and Regional Development", combined with the causes of global warming in "Major Environmental Problems Faced by Humans", teachers should analyze the carbon emission intensity of different transportation modes. They should guide students to think about the optimization path of the transportation structure and connect it with daily life scenarios. This enables students to recognize the cumulative effect of individual choices on emission reduction and transform textbook knowledge into awareness of sustainable behavior. [4]

3.1.2 Supplementing Cutting-Edge Cases and Data

To enhance the timeliness and practical significance of teaching, teachers need to supplement cutting-edge cases and the latest data in the "Double Carbon" field. In renewable energy teaching, such as the Inner Mongolia Chifeng Wind Power Base, whose annual power generation of the Inner Mongolia

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Chifeng Wind Power Base exceeds 2 billion kWh, reducing carbon dioxide emissions by about 1.6 million tons. Combined with the content of "Natural Resources and Human Activities", this visualizes the emission reduction logic of clean energy substitution. Teachers should also cite data from the National Energy Administration---such as renewable energy installed capacity accounting for 48.8% of China's total in 2023---to demonstrate achievements of "Double Carbon" actions.[5] In terms of international experience, they should deeply analyze the Danish model. Wind power accounted for 55% of Denmark's total power generation in 2022, with achieving cost reductions through technological innovations (e.g., 15 MW single-unit capacity). These cases and data not only broaden the international perspective but also help students understand the low-carbon path choices of different countries when combined with the chapter "Connotation of Sustainable Development", providing multiple references for analyzing China's "Double Carbon" strategy.[6]

3.2 Improvement of Teaching Methods

3.2.1 Problem-Driven Teaching

Adopting problem-driven teaching methods, oriented by "Double Carbon"-related issues, can effectively build a bridge between "Double Carbon" education and the cultivation of core literacy in geography, stimulating students' learning interest and initiative.[7] When explaining "Global Warming and 'Double Carbon' Goals", teachers need to design a progressive problem chain based on the knowledge system of the "Environment and Development" chapter, from basic cognition to in-depth exploration. Teachers can start with: "Why do we need to achieve the 'Double Carbon' goals?" This guides students to combine the causes of global warming in "Major Environmental Problems Faced by Humans" and connect carbon cycle principles to analyze the necessity of "Double Carbon" goals for alleviating ecological crises. They can then pose the question: "What challenges will be faced in achieving the 'Double Carbon' goals?" This prompts students to use knowledge points such as "Factors of Industrial Location" and "Regional Development Differences" to discuss technical bottlenecks in the transformation of high-energy-consuming industries and coordination issues regarding emission reduction responsibilities across different regions, as well as to analyze the economic and ecological balance in industrial structure adjustment. Finally, the teacher can conclude with "What actions can we take in daily life to help achieve the 'Double Carbon' goals?", guiding students to think about the emission reduction value of practical activities such as green travel and garbage classification from the perspective of "sustainable consumption", connecting it with the differences in carbon emissions of different transportation modes discussed in "Transportation Layout and Regional Development".

In the exploration process, teachers need to guide students to independently consult authoritative data on the "Double Carbon" special website of the National Development and Reform Commission and to combine textbook cases during group discussions to broaden their thinking perspective through multi-angle analysis. This teaching method not only enables students to deeply understand the connotation and significance of the "Double Carbon" goals---positioning it as both a strategic measure to address global climate change and a specific path to achieve man-earth coordination---but also cultivates their ability to analyze and solve problems, improves their autonomous learning ability, and promotes the transformation of geographical knowledge into practical wisdom supporting "Double Carbon" actions. This lays the foundation for developing ecological civilization literacy.

3.2.2 Situational Teaching Method

As an important path connecting "Double Carbon" education concepts with geography textbook knowledge, the core of the situational teaching method lies in creating concrete and interactive "Double Carbon"-related teaching situations. These guide students to deepen their understanding of theoretical knowledge in the "Environment and Development" chapter and enhance their ability to transform theories into practice through immersive experience.

A simulated situation of "carbon-neutral community construction" can be constructed, relying on core textbook contents such as "Major Environmental Problems Faced by Humans", "Factors of Industrial Location", and "Towards Man-Earth Coordination---Sustainable Development", to design collaborative exploration activities with multiple role participation. In this situation, students play different roles. Through activities such as role interaction, scheme debate, and result visualization presentation, students can intuitively perceive the practical logic of the "Double Carbon" goals. This logic not only originates from the core proposition of "coordinating environment and development" in the textbook but is also specifically reflected in various dimensions such as urban governance, industrial transformation, and daily life. This teaching model not only strengthens students' understanding of the correlation between

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"Double Carbon" goals and geographical knowledge but also stimulates their endogenous motivation to transform theoretical cognition into low-carbon actions, thereby improving their ecological civilization literacy and practical ability.

3.3 Expansion of Teaching Resources

3.3.1 Utilizing Network Resources

The Internet contains rich "Double Carbon" education resources, and teachers can guide students to make full use of them. They should recommend that students pay attention to authoritative platforms such as the "Double Carbon" special work website of the National Development and Reform Commission and relevant websites of the Ministry of Ecology and Environment to obtain authoritative policy interpretations, industry dynamics, and research reports. Teachers should utilize online learning platforms, such as the course "Low-Carbon Economy and Sustainable Development" on China University MOOC, to allow students to access expert explanations and broaden learning channels. Teachers can also collect high-quality popular science videos and documentaries that display the current situation, causes, and impacts of global warming through extensive data and vivid cases. This helps students intuitively feel the urgency of climate change and the importance of "Double Carbon" goals.

3.3.2 Introducing Field Investigation Resources

Combined with local actual conditions, teachers should introduce field investigation resources to allow students to personally experience the practical achievements of "Double Carbon" actions. If there are new energy enterprises, low-carbon communities, or ecological parks locally, students can be organized to conduct field investigations. During the investigation, students learn about enterprises' low-carbon production technologies, communities' energy-saving and emission-reduction measures, and the ecological cycle modes of ecological parks. Through on-site observation and communication with staff, they combine book knowledge with practical application, enhance their perceptual understanding of "Double Carbon" education, and cultivate geographical practical ability.

4. Difficulties in the Implementation of Integrating "Double Carbon" Education

4.1 Barriers to Students' Understanding to Complex Knowledge

Some students have difficulty understanding complex technologies and abstract concepts related to "Double Carbon" and are prone to developing a sense of frustration. This knowledge is interdisciplinary, involving chemistry, biology, statistics, and other fields, which goes beyond the basic scope of senior high school geography. However, textbooks focus primarily on the basic principles of the carbon cycle and provide limited explanation of technical details and interdisciplinary connotations. [8] Although students are aware of "vegetation carbon sequestration", they find it difficult to understand the differences in carbon sequestration capacity among different vegetation types. Similarly, "carbon footprint" is difficult to connect with daily life due to the lack of case support. Teachers need to integrate the textbook content "Relationship between Human Activities and Environment" and reduce the difficulty of understanding through analogy, data visualization, and other methods.

4.2 Insufficient Integration of Teaching Resources

There are three problems in the integration of teaching resources: First, online resources are disorganized, including both policy data from authoritative platforms and non-professional fragmented content. Students find it difficult to distinguish scientificity, and teachers need to spend time screening, increasing the burden of lesson preparation. Second, field investigations are limited. Remote areas lack carriers such as new energy enterprises, and areas with resources also need to coordinate transportation, safety, and other matters, making it difficult to normalize investigations. Third, textbooks are disconnected from cutting-edge developments. Although they contain sustainable development theories, they rarely mention the latest achievements and mechanisms such as carbon trading. Teachers need to continuously supplement, which places high requirements on their information integration ability.

4.3 Need for Improvement in Teachers' Professional Ability

Some teachers have an insufficient systematic grasp of "Double Carbon" knowledge and lack the teaching design ability to deeply integrate "Double Carbon" goals with the core literacy of geography.

ISSN 2522-6398 Vol. 8, Issue 8: 61-68, DOI: 10.25236/FER.2025.080811

"Double Carbon" involves policies, technologies, economy, and other fields. If teachers do not learn systematically, they are prone to stay on superficial explanations, making it difficult for students to understand the "view of man-earth coordination". At the same time, teachers lack the design ability to integrate "Double Carbon" with core geographical literacy, leading to education becoming a pile of knowledge. In addition, "Double Carbon" develops rapidly, and if teachers do not keep up with the latest data and policies in a timely manner, teaching content is prone to lag.

4.4 Difficulty in Transforming Students' Initiative

In traditional teaching, students face double obstacles in transforming "Double Carbon" theories into actions. From the perspective of practice platforms, campus and community activities lack systematic design: there are few "Double Carbon" practice activities in campuses and communities; community practices are mostly one-time publicity, lacking continuous participation mechanisms, making it difficult for students to develop consistent habits. From the perspective of the external environment, the low-carbon atmosphere in families and society has not yet been fully formed: some families value convenience over low-carbon and ignore students' initiatives; social-level problems hinder students' practice. This "disconnection between knowledge and action" is contrary to the "integration of knowledge and action" concept in textbooks, and it is necessary to build a "campus-community-family" collaborative mechanism to promote continuous practice.

5. Teaching Design Integrating "Double Carbon" Education

To concretely demonstrate the integration of "Double Carbon" education into the teaching of the "Environment and Development" chapter, this study proposes a specific teaching design, as detailed in Table 1.

Table 1 Teaching Design of Integrating "Double Carbon" Education into "Environment and Development" Chapter (40 minutes).

Item	Content
Textbook Analysis	The "Environment and Development" chapter in PEP Senior High School Geography Compulsory Volume 2 covers three parts: "Major Environmental Problems Faced by Humans", "Towards Man-Earth Coordination—Sustainable Development", and "Examples of China's National Development Strategies". These are highly consistent with the "Double Carbon" goals (addressing global warming and promoting green development). Textbook knowledge points such as "global warming", "industrial transformation", and "resource recycling" provide a foundation for "Double Carbon" education, but content such as the specific connotation of "carbon peak" and "carbon neutrality", cutting-edge practice cases, and cross-regional emission reduction cooperation need to be supplemented. Combined with the textbook's "Problem Research: How Much Do You Know About Low-Carbon Food", the connection between theory and life practice can be strengthened.
Curriculum Standard Analysis	"Use data to explain the impact of human activities on the environment and understand the importance of coordinating man-earth relations"; "Combine examples to explain the basic connotation of sustainable development";and "use carbon cycle and greenhouse effect principles to analyze the impact of carbon emissions on the environment and explain the importance of international cooperation in carbon emission reduction". "Double Carbon" education is a specific path to implement these requirements. By analyzing the impact of carbon emissions and emission reduction measures, students' views of man-earth coordination, comprehensive thinking, regional cognition, and geographical practical ability are cultivated.
Student Situation Analysis	Senior high school students have mastered basic concepts such as "global warming" and "sustainable development" and have certain logical thinking and data analysis abilities. However, they have little understanding of the specific connotations and realization paths of " Double Carbon" goals. While they pay attention to real-life issues and are interested in topics such as new energy and low-carbon life, they lack the awareness and ability to transform theories into actions. Additionally their interdisciplinary knowledge reserve is insufficient,

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	making it difficult for them to understand complex concepts.
Teaching Objectives	1. View of man-earth coordination: Understand that "Double Carbon" goals are important measures to coordinate the relationship between human activities and geographical environment, recognize that low-carbon development is a key path to achieve man-earth coordination, and establish the concept of low-carbon development; 2. Comprehensive thinking: Analyze the realization path of "Double Carbon" goals from economic, social, and ecological perspectives, and understand the interaction of various elements; 3. Regional cognition: Compare the differences in "Double Carbon" practices in different regions, and understand the imbalance of regional development and the necessity of international cooperation; 4. Geographical practical ability: Improve the ability to use geographical knowledge to solve practical problems through activities such as designing "Family Low-Carbon Day" plans and analyzing local new energy cases.
Key and Difficult Teaching Points	Key points: The connotation of "Double Carbon" goals (carbon peak, carbon neutrality) and realization path; the relationship between "Double Carbon" and sustainable development. Difficult points: Analyzing the synergistic impact of industrial transformation and energy structure adjustment on "Double Carbon" goals from the perspective of comprehensive thinking; transforming the "Double Carbon" concept into practical actions.
Teaching Methods	Lecture method, situational teaching method, problem-based teaching method, group cooperative inquiry method, multimedia-assisted teaching, exercise method.
Teaching Process	I. Introduction (5 minutes) [Teacher's Activity] Use multimedia to play two videos—① Arctic ice cap melting leading to reduced living space for polar bears; ② Operation scene of windmill groups in Inner Mongolia Chifeng Wind Power Base. Ask: "What is the connection between the environmental problems and response measures reflected in the two videos?" Guide students to focus on "carbon emissions" and "low-carbon transformation". [Student's Activity] Watch the videos, combine the textbook knowledge of "global warming", think about the relationship between environmental problems and human activities, and try to connect "emission reduction" with "energy transformation". [Design Intention] Intuitively present problems and solutions through multimedia, stimulate interest, connect existing knowledge, and lay the foundation for understanding the necessity of "Double Carbon" goals. II. New Lesson Teaching (25 minutes) 1. Interpreting "Double Carbon" goals (7 minutes) [Teacher's Activity] Use multimedia to display the "carbon cycle diagram", explain the connotation of "carbon peak" (carbon emissions reach a peak in 2030 and then decline) and "carbon neutrality" (artificial emissions balance with natural absorption in 2060) with the lecture method and supplement data such as: "The installed capacity of renewable energy in China accounted for 48.8% in 2023" to strengthen data support. [Student's Activity] Complete the exercise—label "carbon emission sources" (e.g., industry, transport) and "carbon absorption pathways" (forests, oceans) in the "carbon cycle diagram" to consolidate conceptual understanding through practice. [Design Intention] Break through abstract concepts with multimedia visualization tools, strengthen cognition with exercise method, and lay the foundation for subsequent learning. 2. Exploring "Double Carbon" realization paths (12 minutes) (1) Situation creation: Adopt situational teaching method, set the situation of "building a carbon-neutral community", divide students into 3 groups to play the roles of "community managers", "enterprise operators", and "residents" respectively. (2) Problem chain design (problem-based teaching method): ① Community managers: How to optimize the community's energy structure?

ISSN 2522-6398 Vol. 8, Issue 8: 61-68, DOI: 10.25236/FER.2025.080811

	② Enterprise operators: How to transform high-energy-consuming factories? ③ Residents: What low-carbon behaviors can be adopted in daily life? [Teacher's Activity] Provide data packages, guide group discussions, and answer questions during patrol. [Student's Activity] Conduct group cooperative inquiry, design schemes combined with data packages, and each group selects a representative to share. [Design Intention] Transform abstract theories into specific practices through situational simulation and group cooperation, and cultivate comprehensive thinking and geographical practical ability. 3. Understanding regional differences and international cooperation (6 minutes) [Teacher's Activity] Use multimedia to display the "Comparison Table of 'Double Carbon' Practices between China and Denmark", ask: "Why are the emission reduction paths of the two countries different?" Guide students to pay attention to differences in regional resource endowments. [Student's Activity] Combine the textbook knowledge of "regional development differences", discuss the causes of differences in groups, and recognize the necessity of international cooperation. [Design Intention] Cultivate regional cognition through regional comparison and strengthen the view of man-earth coordination in "global climate governance". III. Lesson Summary (5 minutes) [Teacher's Activity] Sort out the knowledge framework with a mind map—"Double Carbon" connotation → realization paths (energy, industry, life) → core: man-earth coordination; emphasize that "Double Carbon" requires the joint participation of the country, enterprises, and individuals. [Student's Activity] Supplement and improve the mind map, and mark emission reduction actions that individuals can participate in. [Design Intention] Strengthen knowledge structuring, echo teaching objectives, and guide students to transform from "cognition" to "action". IV. After-Class Assignment (5 minutes) [Teacher's Activity] Assign two tasks—① Exercise: Complete the "Carbon Emission Calculation Table for Different Transportation Modes"; ② Practice: Design a "Family Low-Carbon Day Plan" and record behaviors and emission reduction effects. [Student's Activity] Complete the exercise independently, implement the low-carbon plan with family members, and share the results in the next class. [Design Intention] Consolidate knowledge with exercise method, improve geographical practical ability with practical tasks, and strengthen "integration of knowledge and action".

6. Conclusions

Integrating "Double Carbon" education into the teaching of "Environment and Development" in PEP Senior High School Geography Compulsory Volume 2 can effectively improve students' understanding and application ability of "Double Carbon" knowledge, and enhance their environmental awareness and social responsibility through innovating teaching content, improving teaching methods, and expanding teaching resources. This teaching innovation enriches the connotation of geography teaching and provides a useful attempt for cultivating talents adapting to the needs of the times.

In the future, the integration of "Double Carbon" education in geography teaching should be deeper and more extensive. This study suggests that in terms of teaching content, educators should continuously pay attention to the latest research results and practical progress in the "Double Carbon" field, update and enrich teaching materials to ensure timeliness and cutting-edge relevance; strengthen in-depth development of textbooks, organically integrate "Double Carbon" education with other knowledge points in geography, and build a complete knowledge system. In terms of teaching methods, it is necessary to further explore diversified teaching modes, create immersive learning environments combined with modern educational technologies (such as VR, AR); strengthen the application of project-based learning and inquiry-based learning, and organizing more "Double Carbon"-related practical projects. In terms of teaching evaluation, schools should establish a diversified system, focus on process evaluation and practical performance, and set up "Double Carbon"-related evaluation indicators.

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