

Reconstruction of the Four-Dimensional Content System and Innovation of the Digital-Intelligent Teaching Model for Climate Change Economics from the Perspective of Ecological Civilization

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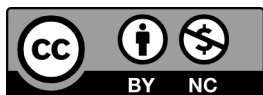
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Abstract: Against the backdrop of China's carbon peaking and carbon neutrality strategy and ecological civilization construction, Climate Change Economics, as a core course in energy economics, needs to meet the requirements of the new liberal arts and help cultivate compound green governance talents. However, existing courses have problems such as fragmented content, insufficient interdisciplinary integration, lagging digital-intelligent application, and weak practical links, making it difficult to meet this demand. Guided by the concept of ecological civilization, this study constructs a four-dimensional content system of "Harmonious Coexistence, Green Development, Inclusive Livelihood, Global Governance", innovates the digital-intelligent teaching model, and establishes a virtual simulation platform and an industry-education integration practice system. Teaching practice has shown that the four-dimensional system has significantly improved students' understanding level of the climate-economic system, and digital-intelligent methods have enhanced the depth of learning, forming a closed-loop of competence cultivation featuring "theory, simulation, practice, innovation". This study provides an operable path for curriculum reform, and also offers a theoretical basis and practical paradigm for the promotion of climate economics education and the construction of new liberal arts.

Keywords: Ecological civilization; Climate Change Economics; Digital-intelligent teaching; Curriculum reform



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1 Introduction

Global climate governance has entered a new phase of in-depth implementation, and China's "carbon peaking and carbon neutrality" strategy is driving the energy-economic system to accelerate its green and low-carbon

Research/Funding project: Teaching Reform Project of China University of Petroleum (Beijing) "Research on Digital-Intelligent Empowerment of Teaching Reform in Climate Change Economics".

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Article Citation: Zhu, Q. T., Wan, Q. C., Lin, J. Y., Liang, Y. L., Liu, L., & Wu, J. (2025). Reconstruction of the Four-Dimensional Content System and Innovation of the Digital-Intelligent Teaching Model for Climate Change Economics from the Perspective of Ecological Civilization. *Guide to Education Innovation*, 5(4), 155-164.

transformation (He, 2020). Against this backdrop, higher education urgently needs to cultivate compound professionals with comprehensive knowledge structures, digital-intelligent application capabilities, and green governance literacy (Li et al., 2025; Chen & Chen, 2025). Tang (2024) further points out that the realization of the dual-carbon goals relies on an interdisciplinary talent training system to empower the transformation of the energy-economic system (Tang, 2024). As a core course connecting climate science, economics, and policy practice, the teaching quality of Climate Change Economics is directly related to the effectiveness of talent cultivation in supporting the dual-carbon strategy. Meanwhile, Roschelle et al. (2020) highlight that the rapid advancement of digital-intelligent technologies, especially artificial intelligence, has paved the way for significant innovation in educational models (Roschelle et al., 2020). These technologies are poised to overcome the limitations of traditional teaching methods by enabling personalized learning experiences, enhancing educational quality, and promoting greater educational equity. Currently, although talent cultivation in China's field of Climate Change Economics has embarked on a path of rapid development (Liu et al., 2023), university curriculum teaching still faces prominent problems such as fragmented content and disconnected practical links. Based on this, this study focuses on three core questions: (1) How can an interdisciplinary content system be constructed to align with the concept of ecological civilization, drawing from practical examples and case studies? (2) Innovating the digital-intelligent teaching model to overcome traditional teaching bottlenecks involves leveraging AI and digital technologies to personalize learning, enhance teaching efficiency, and promote educational equity. (3) How to build an industry-education integration practice system to achieve accurate alignment between theoretical teaching and industrial needs?

This study proceeds in accordance with the following logical framework: First, conduct a thorough analysis of the current state of curriculum instruction, identifying the primary challenges and pain points; Second, construct a four-dimensional content system of "Harmonious Coexistence, Green Development, Inclusive Livelihood, Global Governance" from the perspective of ecological civilization; Third, innovate the digital-intelligent teaching model and the three-level industry-education integration practice system; Finally, evaluate the reform effectiveness and prospect future directions. This framework provides comprehensive theoretical support and practical guidance for the curriculum reform of Climate Change Economics.

2 Analysis of Teaching Status Quo and Existing Problems

To accurately grasp the practical urgency of the curriculum reform of Climate Change Economics, this study adopts diversified methods such as literature analysis, interview surveys, and student questionnaires to conduct a systematic evaluation of the teaching status quo of this course in domestic universities. The research finds that the current course has four core problems: first, a fragmented content system with insufficient cross-field integration; Second, a rigid traditional teaching model with a lack of interactive experience; Third, lagging application of digital-intelligent tools with a disconnection in competence cultivation; Fourth, a weak practical teaching system lacking industry-education integration. These issues have hindered the course's ability to cultivate compound talents, necessitating urgent systematic reform.

2.1 Fragmentation of the Curriculum Content System and Defects in Cross-Field Integration

Although the number of Climate Change Economics courses offered by domestic universities has been increasing

year by year, most of the course content still centers on the single-disciplinary framework of traditional economics, focusing on internal economic areas such as externality, cost-benefit analysis, and carbon pricing mechanisms. This results in an obvious fragmentation of the curriculum system — each knowledge module lacks interdisciplinary connections, and there are significant gaps in integrating with cross-field needs:

First, the knowledge modules of natural sciences and economics are fragmented and isolated, lacking sufficient interdisciplinary integration. Climate Change is essentially the dynamic interaction between the natural system and the human economic system. However, current educational curricula tend to oversimplify the natural science principles, such as the greenhouse effect, and IPCC climate scenarios, treating them merely as background information without effectively integrating them into the construction of economic models. The complexity of climate physical feedback mechanisms, as detailed by the DICE model and other climate research, can make it challenging for students to grasp the intricate linkages with economic decision-making processes (Legg, 2021).

Second, macro policy analysis and micro equity perspectives are fragmented and separated, with a lack of integration in the social field. The varying impacts of climate change on the energy burdens faced by low-income groups and the ecological risks in vulnerable areas have not garnered sufficient attention. Most courses focus on macro policy analysis and lack the integration of micro perspectives such as behavioral economics and public management, leading to a content tendency of “emphasizing efficiency over equity”.

Third, domestic course content is fragmented, lacking integration with international governance dynamics and demonstrating weak connectivity in the global context. International regulations, including Nationally Determined Contributions under the Paris Agreement and the Carbon Border Adjustment Mechanism, significantly shape the global energy economic landscape by influencing CO₂ emission reduction strategies and energy systems (Paris Agreement, 2015). However, most courses merely provide a superficial interpretation of treaty provisions, neglecting to integrate practical issues such as geopolitical games and global carbon concerns, and failing to integrate the evolutionary logic of the international climate system and the dynamics of great-power games into the curriculum content system.

2.2 Rigidity of the Traditional Teaching Model and Lack of an Interactive Experience Mechanism

The traditional teaching model of Climate Change Economics has dual core flaws, which are specifically manifested in two aspects. On the one hand, the model is rigidly confined to the traditional paradigm of “static presentation + one-way indoctrination”: First, the static presentation of models like DICE and RICE in traditional teaching methods hinders the transmission of dynamic logic — the intricate multi-variable feedback mechanisms that are central to these climate economic models are often reduced to static formulas and conclusions (Nordhaus, 2007, 2019). This approach fails to demonstrate the dynamic interplay between parameter adjustments and outcome variations, which is crucial for students to grasp the models’ true complexity. To grasp the dynamic logic underlying the models. Second, the rigidity of the one-way indoctrination model inhibits the stimulation of higher-order thinking — the course content is highly theoretical, and traditional teaching mostly adopts the passive mode of “teachers lecture — students listen”, without setting up interactive links such as critical discussions and multi-perspective debates, leading to students’ difficulty in deepening their understanding of complex policies. Third, the rigidity of the case and evaluation systems intensifies the disconnection in knowledge application — case selections predominantly consist of classic static cases, lacking real-time updates on climate economic hot events, thus creating a gap between theory and reality; evaluation primarily relies

on closed-book exams, emphasizing the assessment of memorization-based knowledge points while neglecting the evaluation of problem-solving and scheme design abilities.

On the other hand, there is a lack of an interactive experience mechanism: under the traditional model, there is insufficient in-depth connection with real scenarios, and no interactive scenarios such as field investigations have been built, leading to students' inability to transform theoretical knowledge into practical capabilities; the group collaboration mechanism is formalized — even when discussion sessions are arranged, they mostly involve superficial opinion - sharing, lacking structured task design (such as collaboration on interdisciplinary policy simulation schemes); the role positioning of teachers and students is overly rigid — teachers dominate all stages, leaving students to passively receive knowledge, which hinders their active participation in problem design and research practice. The core issue lies in the systematic absence of a traditional interactive mechanism.

2.3 Lagging Application of Digital-Intelligent Tools and Disconnection in Competence Cultivation

Leveraging digital-intelligent tools, such as artificial intelligence, is pivotal for enhancing climate economics by enabling more accurate climate change predictions and effective response strategies. The Climate Change Economics course has obvious problems of lag and disconnection in tool application and competence cultivation, which are specifically manifested in three key shortcomings.

First, the delayed adoption of specialized modeling tools and a gap in the development of dynamic simulation skills — climate economic analysis heavily relies on sophisticated tools such as Integrated Assessment Models and energy system optimization models. However, in current teaching practices, the application of tools is limited to static Excel calculations or simple demonstrations, and no operation training on professional models such as DICE is carried out. Students are unable to independently explore the dynamic interplay among variables, mechanisms, and outcomes, leading to a gap in the cultivation of dynamic simulation skills.

Second, lagging application of digital-intelligent data resources and virtual simulations, and disconnection in real-scenario analysis competence cultivation — the course lacks a standardized, dynamically updated digital-intelligent data resource repository. Dispersed data sources, such as IPCC reports, National Bureau of Statistics data, and enterprise annual reports, compel students to invest significant time in data cleaning and integration, thereby diverting their attention from analysis. At the same time, the data type is predominantly macro-statistical, lacking segment-specific data, which hinders micro-policy simulation and case studies. Moreover, no virtual simulation scenarios have been constructed, which further undermines real-scenario analysis capabilities and results in a gap in relevant cultivation.

Third, there is a lag in the application of AI-enabled tools and a disconnect in the cultivation of personalized and practical competencies. Against the backdrop of the rapid development of intelligent education technology, the course remains at the traditional informatization stage. It has not used AI tools to optimize teaching processes (e.g., automatic correction of intelligent question banks, analysis of learning behavior data), resulting in teachers having to undertake excessive repetitive tasks and students receiving insufficient personalized guidance. No AI-assisted decision-making modules have been developed, thus preventing students from experiencing the practical application of digital-intelligent tools in addressing climate economic issues, leading to a gap in the development of personalized and practical competencies.

2.4 Weaknesses of the Practical Teaching System and Absence of the Industry-Education Integration Mechanism

As a key link connecting theoretical knowledge with industry applications in climate governance, practical teaching should support students in developing compound practical capabilities. However, the current course has significant shortcomings in practical system construction and the industry-education integration mechanism:

First, the practical content system is relatively weak, exhibiting insufficient localization and inadequate adaptability to industry demands. Read the transformation cases of domestic energy enterprises. Consequently, students have only a vague understanding of the core challenges in the energy industry, such as carbon quota management and cost control of low-carbon technologies. Existing cases are mostly international experiences or purely theoretical scenarios, devoid of raw data and process materials derived from real-world business scenarios of domestic enterprises. Consequently, students find it challenging to translate the climate economic models learned in class into practical capabilities for addressing real-world industry problems.

Second, the design of practical processes is formalized, leading to a broken closed-loop of competence cultivation. Practical sessions still predominantly involve students independently conducting literature-related task reviews followed by class presentations. They are missing key links, including group collaboration, tool operation, and scheme demonstration, which prevents the formation of a complete competence chain encompassing problem orientation, tool application, and scheme output. For instance, when undertaking practical tasks related to carbon pricing, students are limited to summarizing policy key points through literature review, lacking the ability to utilize professional tools for carbon price simulation or cost-benefit analysis, nor can they propose feasible policy suggestions for specific industries.

Third, the industry-education integration mechanism is absent, with insufficient depth in collaborative talent cultivation. The cooperation among universities, energy enterprises, and research institutions is largely confined to superficial engagements, exemplified by occasional lectures delivered by industry experts or brief one-week internships for students. Furthermore, there is a notable absence of stable and systematic collaborative talent cultivation mechanisms, as co-building on-campus practice bases or inviting enterprise mentors to deeply participate in curriculum design and practical guidance. This loose cooperation model fails to establish an effective linkage among teaching, scientific research, and employment. While students' reports often consist of theoretical analyses, there are successful examples where students engage in practical decision-making processes, such as through business simulations and case studies, which can be valuable for enterprises. This results in students having insufficient recognition of the practical value of practical sessions and a progressive decrease in learning motivation.

In summary, the current Climate Change Economics course faces systematic problems in teaching practice. Therefore, the curriculum reform will be promoted in coordination with two core dimensions: first, guided by the systematic concept of ecological civilization, construct an interdisciplinary integrated content system to realize the organic integration of natural science foundations, economic transformation mechanisms, social equity dimensions, and practical applications. Global governance perspectives; second, rely on digital and intelligent technologies to innovate the teaching model, and strengthen the in-depth coupling of virtual simulation, case discussion, and field practice.

These two reform dimensions will be implemented through specific designs in the subsequent "Reconstruction of the Four-Dimensional Content System" and "Innovation of the Digital-Intelligent Teaching Model", jointly facilitating the course's transition from traditional knowledge transmission to an integrated competence cultivation paradigm of knowledge, tools, and practice.

3 Reconstruction of the Four-Dimensional Content System

The perspective of ecological civilization provides a value foundation for the systematic integration of curriculum content. According to the holistic logic of ecological civilization, this study constructs a four-dimensional teaching framework of “Harmonious Coexistence, Green Development, Inclusive Livelihood, and Global Governance” to guide the knowledge reconstruction of the Climate Change Economics course. This framework not only offers structural support for the curriculum content but also facilitates the upgrade of the competence cultivation path, transitioning from knowledge transfer to value guidance through multi-disciplinary integration.

3.1 Harmonious Coexistence

The harmonious coexistence dimension is based on natural sciences and systematically integrates the physical mechanisms of climate change, such as the impact of greenhouse gases and the constraint relationship of the Earth’s orbit variations, to understand the complex interactions within the climate system. economic system. By strengthening natural science basic contents such as the greenhouse effect, carbon cycle, and radioactive forcing, it helps students establish a scientific cognitive framework of climate change; By analyzing the IPCC climate scenarios, students are guided to grasp the fundamental principle that economic development should be pursued within the sustainable limits of resource and environmental capacity, acknowledging the stringent natural constraints on economic activities; it focuses on elucidating the dynamic feedback mechanism between the carbon cycle and economic growth, exemplified by the influence of climate sensitivity on emission reduction costs and the pathway through which extreme weather events affect the industrial chain. This approach transcends the limitations of traditional economics, which often overlooks the fundamental role of the natural system, and fosters a closed-loop understanding of natural constraints, economic responses, and system equilibrium.

3.2 Green Development

The green development dimension focuses on the low-carbon transformation law of the economic system and realizes the deep integration of classic theories and industry practices. On the basis of sorting out core economic frameworks such as externality theory, carbon pricing mechanism, and green innovation, it focuses on embedding the practical logic of energy industry transformation, such as cost-benefit analysis of low-carbon technology application by oil and gas enterprises and market game mechanism of renewable energy substitution; combined with China’s dual-carbon policy dynamics, it analyzes the economic driving factors of industrial structure adjustment and energy consumption revolution; by introducing machine learning methods to predict and analyze carbon price fluctuations and industrial low-carbonization levels, it cultivates students’ ability to use quantitative tools to solve practical economic problems. It promotes the transformation of economic theories from abstract models to industry practical operations.

3.3 Inclusive Livelihood

The inclusive livelihood dimension enhances the micro-level analysis of climate economics from a social equity perspective, constructing a transmission framework that links macro policies, meso groups, and micro individuals. By analyzing the energy burden disparities among different income groups due to climate change and the varying

ecological risks in vulnerable areas, it reveals social inequality issues in climate governance; introduces the concept of just transition, discusses the distribution effect of policies such as carbon tax and carbon market and the design of compensation mechanisms, such as reemployment training support for employees in high-energy-consuming industries and energy subsidy policies for low-income families; emphasizes the policy evaluation logic oriented by people's livelihood needs, guides students to understand the decision-making mechanism of public climate behavior through micro surveys, and integrates social equity goals into climate economic policy analysis, compensating for the content deficiencies in traditional courses that prioritize efficiency over equity.

3.4 Global Governance

The global governance dimension adopts a global perspective and systematically incorporates the evolution of international climate systems and the logic of geopolitical games. Based on international agreements such as the UNFCCC and Paris Agreement, it analyzes the rule formation mechanism of the global climate governance system and the coordination path of Nationally Determined Contributions; focuses on analyzing the impact of policy tools such as the Carbon Border Adjustment Mechanism and global carbon market linkage on the global energy economic pattern, especially The Carbon Border Adjustment Mechanism is expected to have a significant negative impact on China's high-energy-consuming industry exports, particularly in the short term, as indicated by studies using the GTAP model; combined with cases of great power climate games, it discusses the interest coordination mechanism between developing and developed countries with respect to emission reduction responsibilities, technology transfer, and financial support, fosters students' comprehensive capability to analyze climate economic issues from a global governance standpoint, and achieves the organic integration of local practices and international perspectives.

The aforementioned four-dimensional content framework achieves the systematic integration of multidisciplinary knowledge through the logical chain encompassing natural foundations and economic transformation, social equity, and global coordination, which not only responds to the requirement of ecological civilization construction for compound knowledge structure but also provides a content carrier for the subsequent innovation of digital-intelligent teaching models.

4 Innovation of Digital-Intelligent Teaching Model

To realize the teaching implementation of the four-dimensional content system, this study constructs a teaching model that deeply integrates theoretical teaching, virtual simulation, case discussion, and practical application, supported by digital tools and intelligent technologies. This model breaks the time and space limitations of traditional teaching through technology empowerment, promotes the transformation from knowledge transfer to ability cultivation, and forms a full-chain cultivation path covering cognition, application, and innovation.

4.1 Construction of Virtual Simulation Experiment Platform

Relying on the independently developed Climate Economy Integrated Assessment System, a virtual-real integrated experimental teaching platform is built. This platform integrates multi-scale climate economic models, allowing students to independently set critical parameters such as GDP growth rate, carbon emission intensity, and technological progress.

It dynamically simulates temperature change trends, emission reduction cost curves, and social welfare impacts across various scenarios, offering a visual interface that presents the dynamic feedback of these simulations. The process between the carbon cycle and the economic system, which helps students intuitively grasp the nonlinear impact of natural factors like climate sensitivity on the economic system, thereby compensating for the drawback that complex models are hard to visualize in traditional teaching; it incorporates typical policy simulation modules, such as those for deducing the combined effects of carbon tax and carbon market, and optimizing energy structure transformation paths, enabling students verify policy assumptions by adjusting parameters and develop skills in model construction and policy evaluation.

4.2 Digital-Intelligent Case Teaching System

A dynamic case library is constructed by leveraging a four-dimensional content framework, ensuring the selection of localized cases that align with each dimension (such as low-carbon transformation of energy enterprises corresponding to green development, regional climate policy practice corresponding to inclusive livelihood, international climate negotiations corresponding to global governance, etc.). Case teaching employs the four-step approach: “Scenario Introduction, Problem Disassembly, Model Application, Conclusion Reflection”: taking the case of emission reduction technology application by domestic oil and gas enterprises as an example, it guides students to integrate the cost-benefit analysis theory within the green development framework, and utilize the A virtual simulation platform can be utilized to model the investment return cycles for technology under various carbon pricing scenarios, offering insights into the industrial low-carbonization pathways through data visualization. The program regularly incorporates the latest developments in the Carbon Border Adjustment Mechanism (CBAM), a policy designed to prevent carbon leakage and promote global climate governance. It includes role-play exercises that simulate global negotiations, allowing students to adopt the perspectives of different nations and understand how geopolitical factors influence climate policies. policies, and improve cross-cultural communication and strategic analysis abilities.

4.3 Reform of Classroom Teaching Model

The flipped classroom model of “Problem-Oriented, Tool-Supported, Collaborative Inquiry” is implemented: before class, micro-lecture videos and preview tasks are pushed through the online learning platform to guide students to independently sort out the theoretical framework; in class, the form of “teacher guidance + group discussion” is adopted to carry out collaborative learning around practical problems such as The optimization of regional energy structures under the dual-carbon goals involves strategic planning and policy implementation, as evidenced by the transformation of the coal triangle area in China and the situation in Henan Province. These regions are actively seeking to balance the transition from traditional fossil fuels to renewable energy sources while ensuring energy security and economic development., use the virtual simulation platform to verify discussion assumptions in real time, and teachers adjust teaching focus through process data feedback; AI-assisted teaching tools (such as intelligent question banks for automatic generation of personalized exercises, learning behavior analysis systems for identifying knowledge weak points) are introduced to achieve precise tutoring; classroom interaction adopts forms such as real-time voting and policy debate, combined with data resources of the dynamic case library, allowing students to deepen their understanding of the complex climate economic system in thinking and debate, and cultivate critical thinking and decision-making abilities.

4.4 Industry-Education Integration Practice System

Jointly build practice teaching bases with energy enterprises and research institutions, and construct a three-level practice chain of on-campus simulation, enterprise training, scientific research participation: on campus, complete basic skill training, such as enterprise carbon emission accounting and carbon market transaction simulations, relying on the virtual simulation platform; off campus, organize students to participate in research on low-carbon transformation projects at domestic energy enterprises, collect first-hand data, use the models learned in class to evaluate policy effects, and compile practical reports enterprise collaboration; partner with research institutions, such as the Chinese Academy of Sciences, to establish innovation projects, motivate students to engage in research projects, including climate economic model optimization and economic analysis of low-carbon technologies, and transform excellent results into teaching cases or academic papers. Through industry-education integration, a dynamic linkage between teaching content and industry demands is established, and students' comprehensive ability to solve practical problems is cultivated, facilitating a seamless transition from theoretical learning to industrial practice.

The digital-intelligent teaching model offers an operable implementation pathway for the four-dimensional content system by systematically integrating technical tools (e.g., virtual simulation platforms, AI-assisted tools), teaching methods (e.g., flipped classrooms, case teaching), and practical resources (e.g., industry-education integration bases). The virtual simulation platform strengthens the intuitiveness of theoretical cognition, the dynamic case library improves the pertinence of knowledge application, the flipped classroom enhances the interactivity of the learning process, and the industry-education integration practice ensures the implementation of ability cultivation. The four cooperate to form a closed-loop teaching system of theory, simulation, practice, and innovation, effectively supporting the realization of the compound talent cultivation goal.

5 Conclusion and Prospect

This study systematically addresses the pain points of traditional teaching through three core innovations: First, constructing a four-dimensional content system of “Harmonious Coexistence, Green Development, Inclusive Livelihood, Global Governance” guided by the concept of ecological civilization, realizing the organic integration of natural science foundations and economic governance logic; Second, innovating the digital-intelligent teaching model, developing the Climate Economy Integrated Assessment System and virtual simulation platform, thereby forming a closed-loop teaching system encompassing “theory-simulation-practice-innovation”; Third, establishing a three-tiered industry-education integration mechanism comprising “on-campus simulation, enterprise training, and research participation” to facilitate dynamic alignment between teaching content and industry demands. The core innovation value lies in overcoming the fragmented limitations inherent in traditional courses to achieve interdisciplinary integration; deep adaptation of digital-intelligent tools to teaching scenarios, improving learning efficiency and depth; and the industry-education integration mechanism ensuring seamless connection between theory and practice, enhancing the targetedness of talent cultivation.

Since its launch in 2012, this course has trained more than 500 compound green governance talents and formed a trinity teaching system of “textbook-platform-practice” with remarkable practical results: Compiling the featured textbook *Climate Change Economics* (including student participation in case compilation), developing the Climate

Economy Integrated Assessment System and dynamic resource library, and completing multiple university-level teaching reform projects; students have attained substantial practical achievements, such as compiling enterprise research reports, engaging in scientific research projects like climate economic model optimization, and securing multiple awards in competitions including the Energy Economics Competition and Innovation and Entrepreneurship Competition; establishing a dual feedback mechanism of student questionnaires and teacher self-evaluation, publishing digital-intelligent teaching reform papers, and co-building an internship base with the CAS Institute of Science and Development to realize seamless connection of industry-education integration.

In the future, we will focus on four directions to deepen the curriculum reform: first, facilitate the in-depth integration of artificial intelligence technology with teaching, develop an intelligent teaching diagnostic system, and enable learning behavior analysis and personalized, precise guidance; second, To enhance the course's cutting-edge nature and international perspective, it is essential to expand the interdisciplinary case library by incorporating cutting-edge content such as climate science, geopolitics, and low-carbon technology; third, enhance the functionalities of the virtual simulation platform: introduce AI model optimization and real-time industry data connection to enhance the authenticity and interactivity of simulation practice; fourth, strengthen international industry-education collaboration, collaborate with international universities and energy companies to create cross-border climate governance initiatives, and cultivate compound talents for carbon peaking and carbon neutrality with global competence.

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