ISSN 2663-8169 Vol. 6, Issue 6: 145-149, DOI: 10.25236/IJNDE.2024.060623

"Dual Carbon" Strategy Motivated Teaching Reform of Atmospheric Pollution Control Engineering

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Abstract: *Strengthening atmospheric pollution control is an important measure to achieve the goals of "carbon peak" and "carbon neutrality". As one of the key technologies and important means to reduce greenhouse gas emissions, the education of atmospheric pollution control engineering plays a crucial role in cultivating advanced professionals with specialized knowledge, skills, and innovative thinking. In response to the existing problems in the undergraduate course of "Atmospheric Pollution Control Engineering", this study conducted explorations and practice in curriculum reform closely aligned with the national "dual carbon" major strategy. With a focus on hot issues and based on professional knowledge, this research elaborates on the strategies for curriculum reform in terms of teaching content, pedagogical approaches, and evaluation methods, aiming to cultivate higher-level applied talents in the field of atmospheric pollution control engineering. This study provides valuable references and insights for the teaching reform of the "Atmospheric Pollution Control Engineering" course.*

Keywords: *Atmospheric pollution control, Teaching reform, Dual carbon*

1. Introduction

In recent years, intensified climate change has caused a series of economic, social, and environmental problems globally, impacting the sustainable development of human society and the economy. Countries worldwide have begun to highly prioritize the rational planning of carbon emissions reduction. On November 4, 2016, the first global climate change agreement, the Paris Agreement, came into effect and was approved by 185 out of 197 parties to the United Nations Framework Convention on Climate Change. The agreement requires all parties to communicate ambitious greenhouse gas emission reduction targets to achieve long-term global temperature goals: "to limit the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C." It has been acclaimed as the "most important international agreement in history," "a great leap for humanity," and the "best chance to save our only planet." [1] In September 2020, in his speech at the 75th United Nations General Assembly, President Xi proposed that China strives to achieve carbon peak before 2030 and carbon neutrality before 2060, known as the "dual carbon" goals [2]. The introduction and promotion of the "dual carbon" goals not only demonstrate China's responsibilities as a major global power but also align with China's own development needs in energy, industry, and economic structural transformation and upgrading. It holds significant strategic significance for China to achieve green and low-carbon development and build a socialist modernized country where humans and nature coexist harmoniously. In the context of the "dual carbon" background, education in atmospheric pollution control engineering becomes particularly important.

Environmental Pollution Control Engineering is a core course in the undergraduate program of environmental engineering and an important part of the knowledge system of environmental engineering. Its teaching effectiveness directly affects the theoretical knowledge level and engineering skills of environmental engineering students. This course covers knowledge about the formation mechanisms of atmospheric pollution, control techniques, and purification process design. It is highly interdisciplinary, integrating knowledge from other disciplines such as chemistry, mathematics, meteorology, materials science, and physics. It is comprehensive, extensive, and challenging [3].

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Through this course, students can become familiar with and master the theoretical knowledge of atmospheric pollution concepts, sources, basic principles, and methods of control. They also learn how to apply this knowledge to practical problem-solving, such as comparing, optimizing, improving environmental engineering solutions, as well as engineering management and project consulting. This helps enhance students' professional competence and employment competitiveness, while laying a solid foundation for their future work in environmental management. The course of "Atmospheric Pollution Control Engineering" keeps pace with the times, and its knowledge system and application value continue to receive extensive attention and importance. The guarantee of blue skies and white clouds requires sustained efforts and steady implementation of atmospheric pollution control engineering. However, many current universities still face issues such as outdated teaching content and limited teaching methods in the course of "Atmospheric Pollution Control Engineering," making it difficult to meet the needs of the new era. Therefore, this paper aims to explore how to carry out teaching reform for this course under the background of the "dual carbon" goals, in order to cultivate environmentally conscious talents with innovative spirit and practical abilities.

2. Present Teaching Limits

2.1. Outdated Teaching Content:

Most Chinese universities in the field of environmental engineering use the textbook "Atmospheric Pollution Control Engineering," edited by Hao et al [4]. The teaching content still primarily focuses on traditional emission control technologies, such as basic equipment for particulate matter control, pollution control of sulfur oxides and nitrogen oxides, and volatile pollutant control. This content lags behind in keeping up with the latest international cutting-edge technologies, lacks attention to emerging environmental protection technologies and policies, and hinders students' understanding of the professional direction.

2.2. Limited Teaching Methods:

Lecturers typically follow the structure of textbooks in their teaching, and traditional lecture-based teaching methods fail to meet diverse learning needs. This results in low student engagement and ineffective learning outcomes.

2.3. Insufficient Practical Components:

Atmospheric Pollution Control Engineering is a highly practical discipline; however, many universities currently lack robust practical teaching components, which fail to meet students' actual operational needs.

2.4. Simplistic Evaluation Methods:

The assessment methods for this course usually involve attendance records and exam grades. Objective question types (such as multiple-choice, true/false, and definitions) often carry a higher weightage in exams, while questions involving analysis, synthesis, and arguments are comparatively limited. This assessment approach fails to adequately assess students' problem-solving, analytical, and engineering practical skills.

3. Teaching Reform Strategies

Updating Teaching Content: Effectively connect environmental engineering principles, inorganic chemistry, analytical chemistry, and other related courses to the curriculum of “Atmospheric Pollution Control Engineering”. Review relevant theories and methods from these prerequisite courses, guide students to integrate this knowledge with the course content for better comprehension and mastery. Incorporate the latest scientific research advancements into teaching, providing students with updated content and curriculum systems aligned with social development needs and era requirements. Integrate scientific research outcomes into teaching, fostering mutual promotion between teaching and scientific research, thereby enhancing teaching and talent development quality. Aligning with the "dual carbon" goals, include emerging energy-saving, emission-reduction, and environmental protection technologies and policies in the teaching content, such as CO_2 capture and storage technologies using adsorption, absorption, low-temperature, and membrane systems, as well as low-carbon treatment technologies. Introduce new CO_2 adsorption/absorption materials like metal-organic frameworks (MOFs), ionic liquid absorbents, nano-fluid absorbents, and encapsulated absorbents. It's important to introduce new technologies for ozone and VOCs pollution control. Combined with the research characteristics and advantages of the teaching and research group, the construction technology of sulfur-resistant denitrification catalyst and the preparation of single-atom catalyst are introduced into the course content to broaden students' horizons.

Innovating Teaching Methods: The essence of education is to awaken students' minds, stimulate their intrinsic motivation for learning, and ignite one soul with another. Utilize diverse teaching methods such as case studies, group discussions, laboratory experiments, simulation simulations, and field investigations to enhance student engagement and learning outcomes. Enable students to understand real environmental issues and cultivate their problem-solving abilities. For instance, divide students into several groups, assign each group a topic (such as collaborative removal of NOx and VOCs, latest developments in ionic liquid removal of H_2S, sources and impacts of haze in North China, atmospheric quality in China during the COVID-19 pandemic, etc.), have students research the latest advancements and present their findings, followed by questioning and open discussions. This approach not only encourages active student participation in the classroom, making them the “protagonists” of the class, but also sparks their interest in learning and analysis, while keeping them informed about the latest research trends. Adopting students' active participation in teaching can make the classroom atmosphere more active, thus reducing the number of “head-down people” and increasing the “head-up rate”, and cultivating students' active learning, active thinking and self-analysis and problem-solving ability.

Utilizing platforms like Tencent Meeting, DingTalk, along with various online resources like MOOCs and Rain Classroom, allows breaking traditional teaching constraints in terms of space and time. By providing course materials for replay, students can review the content based on their schedules, especially focusing on key and challenging areas. With over 12,000 online open courses available, MOOC platforms are valuable for students in pre-class preparation, inter-class discussions, and post-class reviews. Rain Classroom, an intelligent teaching tool, allows students to join courses using specific classroom codes or QR codes to access slides and engage in teaching activities. Students can promptly provide feedback to teachers on difficult concepts, participate in discussions through bullet comments, or engage in face-to-face discussions during class, enhancing classroom interactivity. The backend data analysis feature of Rain Classroom enables teachers to visually understand teaching effectiveness, making teaching more engaging, saving time spent on board writing, and enriching teaching content. Through this approach, we aim to provide students with a flexible, interactive, and content-rich online learning environment.

Through social platforms like WeChat and QQ, teachers and students can establish a platform for exchanging information and discussions related to the course of Atmospheric Pollution Control Engineering. Creating WeChat and QQ groups allows sharing of case studies in pollution control, environmental websites, the latest developments in the field, industry trends, and related competition information. Additionally, current job market conditions and demands can also be discussed on these platforms. These communication platforms not only facilitate communication between teachers and students on course content, academic challenges, teaching feedback, and suggestions, but also ensure timely and effective student learning feedback. Teachers can use these tools to guide students to actively participate in learning, leveraging their initiative and creativity. By effectively utilizing online resources and enhancing interaction between teachers and students, significant improvements in teaching effectiveness can be achieved.

Enhancing Practical Components: Increase the proportion of laboratory courses and practical teaching, encourage student participation in research projects and environmental practice activities to enhance their practical skills and foster innovative thinking. For example, involve students in hands-on activities such as sampling atmospheric particulate pollutants, operating flue gas denitrification devices, and working with photocatalytic VOCs purification units.

Flexible and Varied Assessment Methods: Move away from emphasizing final exams at the expense of professional practice accumulation. Adopt a comprehensive assessment model throughout the course (see Table 1). In addition to traditional exams and paper evaluations, introduce performance-based assessments and practical evaluations. For example, conduct laboratory reports, engineering design and drawing, and on-site practical assessments to comprehensively evaluate students' practical skills and problem-solving abilities, helping them better align with practical engineering practices. Specifically, weekly scores account for 20%: including class assignments, attendance, discussions, and participation;

achievement scores account for 40%: including papers, PPT presentations, engineering designs, and drawings; final scores account for 40%: with questions types comprising multiple-choice, true/false, fill-in-the-blank, short-answer, essay, and calculation questions. Additionally, incorporate some open-ended questions in final exams, such as asking contemporary university students how they can make positive contributions to winning the battle for blue skies. Open-ended questions can assess students' comprehensive and analytical abilities. By implementing a multi-level, multi-content assessment model as mentioned above, students are not only motivated to engage in autonomous learning but are also encouraged to participate actively in classroom discussions, sparking their interest in learning and analysis, and comprehensively assessing their learning progress and understanding of course content.

Table 1: Indexes Used for Teaching Assessment.

Sub-item (of program)	Evaluation Content	Percentage	Assessment Method
Performance grades	Class assignments, attendance, Class discussions and presentations	20%	Teacher scoring Student mutual Assessment
Achievements	Essay, PPT presentation, Engineering design and drafting	40%	Teacher scoring Student mutual Assessment
Examination results	Basic theory learning	40%	Closed book exam

4. Teaching Reform Effects

The teaching reform in “Atmospheric Pollution Control Engineering” has received strong support from enrolled students, and the overall progress has been smooth. Throughout the course implementation and upon its completion, feedback on the teaching reform effect was obtained through online surveys on Tencent Meeting and face-to-face interactions with students, with the main results shown in Figure 1. The majority of students believe that the new teaching model has effectively expanded the breadth of the teaching content. They have gained insights into the latest advancements in scientific research through the course. Course presentations and student peer evaluations have motivated active learning participation, improved expression, communication, and practical operational skills, and the diversified grading system can effectively reflect learning outcomes.

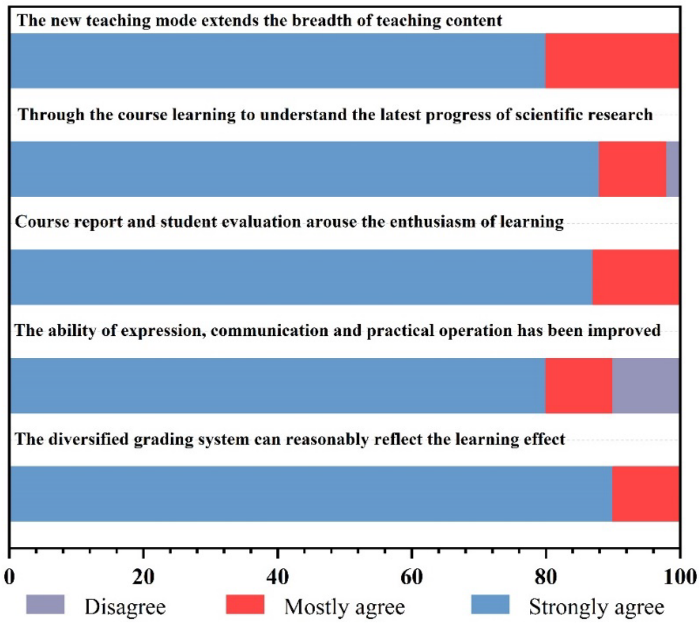

Figure 1: Student feedback on the effectiveness of teaching reform

5. Conclusion and Outlook

In conclusion, the educational reform of the “Atmospheric Pollution Control Engineering” course

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against the background of the “dual carbon” goal involves updating and supplementing course content, innovating teaching methods, and diversifying evaluation methods. These reforms can better equip students to meet real-world demands and cultivate atmospheric pollution control engineering professionals with the necessary expertise, skills, and innovative thinking. However, educational reform is a long-term process that requires continuous exploration and implementation. In the future, we will continue to monitor the development of atmospheric pollution control engineering education under the "dual carbon" goal, continuously improve educational reform strategies, and make greater contributions to the cultivation of environmentally conscious professionals with innovative spirit and practical skills.

Acknowledgements

The authors are grateful to the teaching reform projects supported by Shandong University (list nos.: 2023-112; 2023-393).

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