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# Modular Teaching Reform and Practice of Core Courses for New Energy Majors Under the "Dual-Carbon" Goal—A Case Study of *Solar Energy Utilization Technology*

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**Abstract:** Against the background of comprehensive advancement of the national "Dual-Carbon" strategic goal, China's new-energy industry is developing rapidly, driving the growth of new-energy talents and pointing out the direction for teaching reform and talent cultivation of new-energy majors in universities. Solar Energy Utilization Technology is a core course for new-energy majors and serves as a key "bridge" linking theoretical teaching and practical teaching. Nevertheless, the teaching of this course is confronted with problems including fragmented knowledge systems, untimely updates of teaching content, and unsatisfactory practical-teaching effects, which make it difficult to meet the talent demands of the new-energy industry. Based on the "Dual-Carbon" goal, this paper analyzes the advantages of modular teaching for the course Solar Energy Utilization Technology, dissects the current teaching status of the course, and explores paths for its modular teaching reform. Elaborations are carried out from four aspects: reconstructing teaching modules, deepening digital-intelligent teaching reform, improving the modular practical-teaching system, and optimizing the teaching-evaluation system, aiming to enhance the quality of course teaching and talent cultivation.

**Keywords:** "Dual-Carbon" goal; New-energy major; Modular teaching; *Solar Energy Utilization Technology*

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## 1. Introduction

The "Dual-Carbon" strategy constitutes a major national strategy for China to promote energy-structure transformation and realize green and low-carbon development. Under such a background, photovoltaic power generation and photothermal projects in China are developing rapidly. There is an urgent demand for compound new-energy talents who possess theoretical knowledge of solar-energy utilization, engineering practical capabilities, and low-carbon environmental-protection awareness. Modular teaching caters to the demand for compound new-energy talents in the new era. It can convert course knowledge points into different modules, integrate post skills, engineering design, and practical skills into teaching modules,

and strengthen students' practical abilities, innovative capabilities, and competence in solving complex engineering problems. Therefore, oriented toward the post-demands of the new-energy industry and talent-cultivation objectives, universities shall deepen teaching and talent-cultivation reform for new-energy majors. Taking the course *Solar Energy Utilization Technology* as a pilot, modular teaching shall be implemented. Course knowledge points are decomposed into several teaching modules to realize in-depth integration of course knowledge points, post skills, and engineering practice, helping students master course knowledge points and improve their comprehensive capabilities.

## 2. Core advantages of modular teaching for *Solar Energy Utilization Technology* under the "Dual-Carbon" goal

### 2.1. Aligning with "Dual-Carbon" talent-cultivation objectives and strengthening education for low-carbon literacy

Under the "Dual-Carbon" goal, practitioners in the new-energy industry shall not only have solid professional knowledge and practical capabilities, but also possess good professional-ethics literacy such as green low-carbon awareness, energy-saving and emission-reduction awareness, and craftsmanship spirit [1]. Modular teaching fits the requirements of "Dual-Carbon"-oriented talent cultivation. *Solar Energy Utilization Technology* is divided into modules including fundamentals of solar radiation, photovoltaic power-generation technology, photothermal-utilization technology, system design, operation and maintenance, and low-carbon energy-saving application. Knowledge points concerning energy saving and emission reduction, the "Dual-Carbon" goal, and green development are interspersed in the teaching of each module to foster students' good professional-ethics literacy.

### 2.2. Reconstructing a systematic knowledge system to resolve fragmented-teaching problems

The course *Solar Energy Utilization Technology* integrates multidisciplinary knowledge of physics, material science, and engineering management, featuring both theoretical and practical attributes. Modular teaching can break barriers between chapters and disciplines, reconstruct course-teaching knowledge, and assemble scattered knowledge points into structured and systematic knowledge modules. It closely combines theoretical teaching, practical teaching, and engineering cases, helping students build a complete application system for solar-energy technologies and improve their course-learning outcomes.

### 2.3. Matching industrial post demands and enhancing talent-job adaptability

At present, posts in the solar-energy industry are continuously subdivided into positions such as photovoltaic-system design, power-station operation and maintenance, distributed photovoltaic engineering, and photothermal-system design, with obvious differences in post responsibilities and talent requirements. Modular teaching boasts higher flexibility. It can dynamically adjust the teaching content of each module according to post standards and personnel demands, and add typical cases of photovoltaic-power-generation engineering and system operation-maintenance. It helps students keep abreast of employment trends in the solar-energy industry, master post skills, improve the adaptability between teaching contents of *Solar Energy Utilization Technology* and enterprise talent demands, and lay a sound foundation for students' future employment [2].

## 3. Current teaching status of *Solar Energy Utilization Technology* under the "Dual-Carbon" goal

### 3.1. Rigid teaching contents disconnected from the development of the "Dual-Carbon" industry

At present, textbooks for *Solar Energy Utilization Technology* in universities feature relatively long update cycles. Part of the teaching contents lag behind the development of the solar-energy industry and are disconnected from the "Dual-Carbon" goal, limiting students' understanding of new-energy industries, photovoltaic power generation, power-station operation-maintenance, and other knowledge [3]. For instance, textbooks contain limited content on emerging technologies such as new-type solar cells, low-carbon application technologies, and intelligent operation-maintenance of photovoltaic power stations. Explanations of the "Dual-Carbon" goal focus on theories and lack support from typical cases, which is unfavorable for fostering students' awareness of energy conservation, emission reduction, and green development.

### 3.2. Single teaching mode with insufficient practical classroom-education effects

The teaching of *Solar Energy Utilization Technology* is dominated by explanation of theoretical knowledge. Project-oriented teaching, case-based teaching, and situational teaching modes are seldom adopted. A single teaching mode can hardly arouse students' learning interest, resulting in a dull classroom atmosphere and impaired teaching quality [4]. Meanwhile, digital-intelligent teaching yields unsatisfactory outcomes. It is mostly confined to micro-lectures and blended teaching. Virtual-simulation technology is rarely adopted for practical-training teaching, and knowledge graphs and big-data tools are seldom used for targeted teaching, which hinders the cultivation of students' innovative capabilities, engineering practical capabilities, and professional-ethics literacy.

### 3.3. Weak practical teaching and imperfect practical-training system

Practical teaching of *Solar Energy Utilization Technology* suffers from simple teaching content, which mainly consists of basic experiments such as solar-cell characteristic tests and photovoltaic-power-generatio n-equipment assembly. Comprehensive engineering cases concerning photovoltaic-device design, distributed photovoltaic-engineering design, and photovoltaic-system maintenance are insufficient, which impairs the connection between practical-training content and post-graduation skills. In addition, practical-training teaching lacks cases of photovoltaic power generation and distributed photovoltaic engineering. This weakens the connection between the "Dual-Carbon" goal, post-graduation skills, enterprise talent demands, and course-teaching content, and lowers the quality of practical-training teaching [5].

## 4. Paths for modular teaching reform of *Solar Energy Utilization Technology* under the "Dual-Carbon" goal

### 4.1. Reconstructing teaching modules based on "Dual-Carbon" talent-cultivation objectives

Teachers of new-energy majors in universities shall base themselves on the "Dual-Carbon" goal, clarify industrial post standards and talent demands, actively break barriers between chapters and disciplines, and reconstruct course modules for *Solar Energy Utilization Technology*. Course knowledge points are divided into three major modules: basic knowledge, core-technology application and expansion, and innovative

practice. The teaching contents of each module are adjusted according to new trends in the solar-energy industry to improve the adaptability of course-teaching contents to industrial development and talent demands.

First, the basic-knowledge module includes theoretical knowledge such as principles of solar radiation, principles of solar cells, basic theories of photoelectric-photothermal conversion, and the "Dual-Carbon" goal, so as to consolidate students' professional foundations [6].

Second, the core-technology application and expansion module covers solar-cell technologies, photovoltaic modules and systems, solar-energy-storage coupling technologies, equipment operation-maintenance and fault troubleshooting. Technical standards and equipment parameters of the photovoltaic-power-generation industry are included in this module. It also includes engineering cases of photovoltaic-power-station design, distributed photovoltaic engineering, photothermal heating and industrial low-carbon transformation, promoting the connection between new-industrial technologies, post skills and modular-teaching contents [7].

Third, the innovative-practice module focuses on design, operation and maintenance management of photovoltaic-power-generation projects. Centering on contents such as solar-system design, photovoltaic-panel design optimization, construction, operation and maintenance management of distributed photovoltaic engineering, project-oriented teaching is implemented to cultivate students' innovative capabilities and engineering practical abilities.

In short, the knowledge points of the three major teaching modules are interrelated. They help students understand new technologies, technical standards, and post skills of the solar-energy industry, stimulate their enthusiasm for autonomous learning, encourage them to take initiative in classroom interaction, and thus improve classroom-teaching quality [8].

## 4.2. Deepening digital-intelligent teaching reform and integrating "Dual-Carbon"-oriented classroom education

Teachers shall actively apply digital-intelligent technologies in modular teaching of *Solar Energy Utilization Technology*. On the one hand, generative-AI technologies shall be adopted to produce teaching cases and update teaching contents of each module in a timely manner to facilitate students' online autonomous learning. On the other hand, virtual-simulation practical-training modules shall be designed to simulate scenarios of design, construction, operation, and maintenance management of photovoltaic-power-generation projects for students to conduct online operational exercises and improve practical-training-teaching quality.

For example, teachers can utilize DeepSeek and ChatGPT to collect materials including frontier literature on solar-energy technologies, documents related to the "Dual-Carbon" goal, and cases of pho tovoltaic-power-generation-project design and construction. Such resources shall be demonstrated and screened to guarantee the authenticity and forward-looking nature of digital teaching resources and improve the adaptability of modular-teaching contents to the development of the new-energy industry. Meanwhile, teachers shall timely summarize download volumes of various documents, micro-lectures and cases as well as students' online comments, accurately identify students' knowledge weaknesses and knowledge points of interest, and conduct targeted teaching to satisfy students' personalized-learning demands and improve targeted-teaching quality [9].

In addition, teachers can adopt VR/AR technologies for practical-training teaching and design virtual-simulation practical-training modules. Scenarios such as low-carbon transformation of aging

photovoltaic systems and design-construction of distributed photovoltaic engineering are simulated. Students can assemble photovoltaic-power-generation equipment, debug systems, and formulate construction plans in virtual scenarios to enhance their practical-operation capabilities. The virtual-simulation-experiment system can record and analyze students' operation processes in real time, point out problems in their operations, facilitate targeted exercises, improve students' practical-operation capabilities, provide data support for teachers' practical-training teaching, and comprehensively boost the practical-teaching quality of *Solar Energy Utilization Technology* [10].

## 4.3. Improving the modular practical-teaching system and enhancing engineering operational capabilities

To implement the "Dual-Carbon" goal, universities shall comprehensively deepen industry-education integration and university-enterprise cooperation, and invite enterprises to participate in modular practical teaching of *Solar Energy Utilization Technology*, laying a solid foundation for improving practical-teaching quality [11].

First, universities and enterprises can jointly design basic practical-training modules for *Solar Energy Utilization Technology*. Besides basic verification experiments, comprehensive experiments such as photovoltaic-system design, photothermal-system debugging, and equipment-fault troubleshooting shall be designed to promote the connection between enterprise post skills, industrial standards, and modular practical-training teaching, and further improve practical-training-teaching quality. Real-world engineering projects from enterprises can also be interspersed in basic practical-training modules to introduce cutting-edge achievements, latest technical standards, and equipment parameters of China's photovoltaic-power-generation industry, laying a good foundation for subsequent project-oriented practical-training teaching [12].

Second, enterprise experts can deliver project-oriented practical-training teaching, explaining knowledge including design schemes of distributed photovoltaic engineering, key construction points, equipment faults, and maintenance. Students are guided to conduct inquiry-based learning in group cooperation, so that they can experience the whole process of engineering design, construction, operation, and maintenance management. Their engineering practical capabilities and competence in solving complex engineering problems are enhanced. Through project-oriented practical-training teaching, students can master assembly of photovoltaic-power-generation equipment, system design, common faults and maintenance skills, accumulate more practical engineering experience, and develop good professional-ethics literacy characterized by rigorous attitude, pursuit of excellence, hard-working spirit, low-carbon environmental-protection awareness and teamwork awareness, which lays a solid foundation for their future employment [13].

## 4.4. Constructing a multi-dimensional assessment-evaluation system to promote students' all-round development

Based on the "Dual-Carbon" goal, teachers shall build a multi-dimensional modular-teaching evaluation system to promote the development of students' professional knowledge, post skills, engineering practical capabilities, and professional-ethics literacy [14].

The multi-dimensional modular-teaching evaluation system includes process-oriented evaluation and result-oriented evaluation. Result-oriented evaluation mainly consists of in-class quizzes and final-exam scores. Process-oriented evaluation assesses the teaching process of each module. Evaluation indicators cover students' classroom performance, assignment-completion quality, operational processes in virtual-simulation

practical training, and case analysis. Problems existing in modular teaching and students' learning processes can be detected in a timely way, so that modular-teaching contents and methods can be adjusted to improve the modular-teaching quality of *Solar Energy Utilization Technology*.

In addition, teachers shall take craftsmanship spirit, teamwork awareness, environmental-protection awareness, work ethic, and innovative capabilities as evaluation indicators to promote the integration of ideological-political education and modular teaching and enhance students' professional-ethics literacy [15]. Meanwhile, enterprise experts shall be invited to participate in teaching evaluation. They shall assess students' performance in project-oriented practical training, capabilities for engineering-case design and professional-ethics literacy, so as to promote students' all-round development and realize win-win outcomes for modular teaching and talent cultivation.

## 5. Conclusion

To sum up, oriented toward cultivating compound talents under the "Dual-Carbon" goal, new-energy majors in universities shall actively promote modular teaching reform for *Solar Energy Utilization Technology*. Efforts shall be made in four dimensions: reconstructing course-teaching modules, deepening digital-intelligent teaching reform, building a modular practical-teaching system, and constructing a multi-dimensional evaluation system, so as to improve the quality of modular teaching and talent cultivation. In the future, universities shall actively develop loose-leaf textbooks for *Solar Energy Utilization Technology*, add or delete textbook contents according to development trends of the solar-energy industry to improve textbook-construction quality, build a digital-teaching-resource library, and expand teaching contents. It can provide references for teaching reform of core courses for new-energy majors and cultivation of compound new-energy technical talents.

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