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Exploration of Teaching Reform of the Course "Photovoltaic Power Station Design and Operation and Control" in Applied Undergraduate Colleges: A Case Study of Shandong Institute of Petroleum and Chemical Technology

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Abstract: Against the backdrop of China's "dual carbon" goals, the photovoltaic industry has entered a phase of rapid development, creating an urgent need for applied photovoltaic professionals. As a core course in new energy disciplines, "Photovoltaic Power Plant Design and Operation Control" directly impacts talent cultivation quality. Taking Shandong Institute of Petroleum and Chemical Technology as a case study, this paper addresses challenges including theoretical-practical disconnect, outdated content, insufficient practical resources, and monotonous assessment methods. Through systematic reforms—optimizing curriculum design, innovating teaching approaches, enhancing practical training, and refining evaluation systems—the course has effectively improved students' engineering skills and innovative thinking. These measures, such as implementing project-based learning, establishing hybrid virtual-practical training platforms, deepening industry-academia collaboration, and creating diversified assessment mechanisms, provide valuable insights for curriculum development in new energy programs at applied undergraduate institutions.

1. Introduction

In September 2020, China officially unveiled its strategic goals of "peaking carbon emissions by 2030 and achieving carbon neutrality by 2060," charting a course for energy transition and renewable energy development. As a cornerstone of clean energy, photovoltaic power generation plays a pivotal role in realizing these dual carbon targets. According to the National Energy Administration, China's installed photovoltaic capacity surpassed 600 million kilowatts by the end of 2024, maintaining its global leadership for consecutive years. The industry's rapid expansion has spurred a surge in demand for highly skilled professionals, raising the bar for talent cultivation in photovoltaic-related academic programs[1-4].

Shandong Institute of Petrochemical Technology, an applied undergraduate institution specializing in petrochemical engineering, has actively responded to national energy strategy demands by launching the New Energy Science and Engineering program in 2021. Among its core courses is "Photovoltaic Power Plant Design and Operation Control," which covers photovoltaic cell principles, module selection, power plant design, system integration, and operation maintenance, combining strong theoretical foundations with practical applications. However, teaching practices have revealed that traditional pedagogical approaches fail to meet the requirements for cultivating applied talents, necessitating systematic educational reforms.

2. Current Status and Existing Problems of the Course

Through teaching practice and questionnaire surveys of students from 2021 and 2022 in the New Energy Science and Engineering program at Shandong Institute of Petroleum and Chemical Technology, combined with feedback from peer experts, we have identified the following key issues in the course's teaching:

2.1. Theoretical and Practical Disconnection

Traditional teaching methods predominantly rely on classroom lectures, overemphasizing the systematic nature of theoretical knowledge while neglecting the cultivation of engineering practice skills. Students struggle to connect abstract theories with practical power station design during their learning process, resulting in a pronounced disconnect between theory and application. Surveys indicate that approximately 65% of students perceive theoretical content as overly abstract and difficult to apply in real-world scenarios, which negatively impacts their learning motivation and teaching effectiveness.

2.2. Lag in Updating Teaching Content

The photovoltaic industry is advancing rapidly, with new modules, inverters, and energy storage systems constantly emerging. However, textbooks often lag behind the industry's rapid evolution, retaining outdated content that reflects technologies from years ago. For instance, mainstream innovations like N-type solar cells, bifacial modules, and string inverters are rarely covered in current materials, creating a disconnect between students' knowledge and the industry's actual needs.

2.3. Insufficient Practical Teaching Resources

Photovoltaic power plant design involves multiple stages including site investigation, system configuration, equipment selection, and economic analysis, requiring substantial practical teaching resources. Although the school has established a photovoltaic laboratory, the limited number of experimental devices due to space and funding constraints fails to meet students' needs for large-scale hands-on practice. Moreover, the absence of real power plant scenarios hinders students from gaining comprehensive engineering experience.

2.4. Single Assessment Method

Traditional assessment primarily relies on final written examinations, emphasizing the memorization of theoretical knowledge while neglecting the evaluation of students 'practical skills and innovative thinking. This "single-exam-determines-all" approach fails to comprehensively reflect students' learning outcomes and is detrimental to motivating their academic engagement.

3. Teaching Reform Measures

To address these challenges, we initiated a systematic pedagogical overhaul of the "Photovoltaic Power Plant Design, Operation and Control" course in 2024, with the following key measures:

3.1. Optimize the Curriculum System and Update the Teaching Content

We closely monitor the latest developments in the photovoltaic industry and promptly incorporate new technologies, standards, and regulations into our curriculum. Building upon the existing course framework, we have expanded the syllabus to include cutting-edge topics such as N-type cell technology, bifacial power generation systems, intelligent operation and maintenance, and integrated photovoltaic-storage solutions. Additionally, we have introduced real-world industry case studies, including large-scale photovoltaic power station projects in Shandong Province, to ensure the teaching content remains closely aligned with practical engineering applications.

The curriculum modules are redesigned into five key components: "Fundamentals of Photovoltaics", "Power Plant System Design", "Equipment Selection and Configuration", "Operation and Maintenance of Power Plants", and "Integrated Design Practice", forming a progressive "theory-design-practice" teaching framework.

3.2. Innovate Teaching Methods and Promote Project-Driven Learning

To transform the traditional lecture-based teaching model, we implement Project-Based Learning (PBL). Students work in groups to complete a full-cycle photovoltaic power station design project, covering research, conceptual design, equipment selection, and economic analysis. This hands-on approach cultivates engineering thinking and teamwork skills.

Leverage information technology to establish an online course repository featuring instructional videos, virtual simulation experiments, and case studies. We implement a blended learning model combining online preparation with offline discussions to enhance classroom efficiency. Additionally, we develop a virtual simulation software for photovoltaic power station design, enabling students to complete station designs across various scenarios in a virtual environment, effectively addressing the shortage of practical teaching resources.

3.3. Strengthening Practical Teaching and Deepening School-Enterprise Cooperation

Increase investment in practical teaching by expanding the photovoltaic laboratory and adding experimental projects such as photovoltaic module characteristic testing, inverter debugging, and system design simulation. We have established a partnership with local photovoltaic enterprises in Shandong to jointly build an off-campus practical teaching base, enabling students to visit and learn from these enterprises and participate in the actual project design.

Hire corporate engineers as part-time instructors to establish an "Enterprise Expert Lecture Hall," where they share practical engineering experience and industry frontiers. Through the development of a "dual-qualified" teaching team, theoretical instruction and engineering practice are organically integrated.

3.4. Improve Assessment and Evaluation, Establish a Diversified System

The traditional assessment method will be reformed to establish a diversified evaluation system combining "process assessment + project assessment + final assessment". Process assessment, covering classroom performance, homework completion, and lab reports, accounts for 30% of the total grade. Project assessment evaluates group-designed projects, contributing 40% of the total grade. The final assessment adopts an open-book written test format, focusing on comprehensive application skills, which accounts for 30% of the total grade.

The expert of the enterprise is introduced to participate in the project assessment, and the comprehensive evaluation is made from the dimensions of engineering practicability, technical feasibility and economic rationality, so that the assessment result is more objective and comprehensive.

4. Teaching Outcomes

Through two years of teaching reform practice, the teaching quality of the course "Photovoltaic Power Station Design and Operation Control" has been significantly improved, achieving excellent teaching outcomes.

First, students' learning motivation has significantly improved. The implementation of project-based teaching has transformed students from passive recipients to active explorers, with substantial increases in classroom participation and self-directed learning time. Survey results indicate that 92% of students are satisfied with the reformed teaching model, while 85% believe the curriculum "enhances professional competencies."

Second, students' engineering practice capabilities have been significantly enhanced. Through virtual simulations and real-world project training, they have mastered the fundamental methods and tools for photovoltaic power station design, enabling them to independently complete design proposals for small and medium-sized photovoltaic power stations. Among the 2023 graduates, 15 students joined photovoltaic companies to work in design and R&D, with employers praising their "quick adaptability and solid foundational skills."

Third, outstanding achievements in innovation competitions. Leveraging the outcomes of curriculum reform, students actively participated in academic competitions, winning six provincial-level or higher awards in events such as the National College Students Photovoltaic Innovation Design Competition and the "Internet+" Innovation and Entrepreneurship Competition, including two first prizes.

Fourth, the curriculum development has yielded abundant achievements. The course was awarded the university-level "First-Class Undergraduate Course", and the teaching team was approved for one provincial-level teaching reform project and three university-level teaching reform projects, with four teaching research papers published.

5. Conclusions

The pedagogical reform of the "Photovoltaic Power Plant Design, Operation, and Control" course is a pivotal component in developing new energy-related programs at applied undergraduate institutions. Shandong Institute of Petroleum and Chemical Technology has effectively addressed longstanding challenges in traditional teaching—such as the disconnect between theory and practice, outdated curricula, limited practical resources, and monotonous assessment methods—through systematic curriculum optimization, innovative teaching approaches, enhanced practical training, and refined evaluation mechanisms. These measures have significantly elevated the quality of talent cultivation.

Moving forward, we will deepen our teaching reforms through four key initiatives: First, we will strengthen collaboration with photovoltaic enterprises to develop an order-based talent cultivation model. Second, we will integrate green development concepts and craftsmanship spirit into curriculum design. Third, we will enhance digital teaching resources by creating more high-quality online courses. Fourth, we will actively apply for provincial-level first-class course recognition to serve as a model for industry leadership. Through continuous improvement, we aim to establish this course as a distinctive, top-tier applied undergraduate program, cultivating more high-caliber professionals for the photovoltaic industry.

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