

Innovative Talent Training Model for Energy and Power Engineering Majors under the Dual Carbon Background

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Abstract: To meet the requirements of the dual carbon goals, this study examines talent training reform in energy and power engineering. The reform focuses on three issues: the limited inclusion of emerging energy technologies in course content, insufficient use of research resources in undergraduate education, and weak connections among practical teaching activities. Course content is updated in response to advances in energy technologies, and topics such as hydrogen energy, energy storage, and smart energy are incorporated into professional courses. Research projects and laboratory facilities are used to develop teaching cases, innovation training projects, and undergraduate thesis topics from research outcomes. Laboratory teaching, student competitions, research training, and engineering practice are also more closely connected to improve the continuity of practical training. The results show that these measures strengthen the links among professional education, research training, and engineering practice. They also improve students' ability to apply professional knowledge and develop their engineering and innovation capabilities. The reform provides a practical reference for improving talent training in energy and power engineering in response to the development of new energy systems.

Keywords: Dual carbon goals; Energy and power engineering; Innovation capability; Talent training

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1. Introduction

With the continued pursuit of carbon peaking and carbon neutrality goals, significant changes are taking place in energy production and utilization in China. The Work Plan for Strengthening the Higher Education Talent Training System for Carbon Peaking and Carbon Neutrality, issued by the Ministry of Education, calls for

upgrading traditional energy and power engineering programs, strengthening talent training in smart power generation, distributed energy, and multi-energy complementary systems, and promoting the development of programs related to new energy technologies^[1]. The “dual carbon” goals impose new requirements on the knowledge and competencies of energy and power engineering graduates. Accordingly, training objectives and curricula should be further optimized in response to changes in the energy structure and technological advances^[2]. The curriculum and course content directly affect the quality of talent training. Peng proposed that the curriculum for new energy science and engineering should be improved to strengthen its connection with emerging industries, with greater emphasis on students’ comprehensive competence and innovation capability^[3]. Other studies on energy and power engineering education under the “dual carbon” goals have suggested optimizing training programs and adjusting curricula and course content in response to industrial development and changing talent demands^[4].

Energy and power engineering is characterized by a strong emphasis on engineering practice. Lu et al. integrated research activities and innovation competitions into undergraduate education in energy and power engineering and developed a scientific and technological innovation training approach spanning the undergraduate years^[5]. Lu et al. reformed experimental teaching in energy and power engineering in terms of experimental content, digital resources, teaching methods, and assessment^[6]. Their study highlighted the role of experimental teaching in developing students’ practical and innovative abilities. In addition, incorporating real engineering problems and industrial needs into professional courses can help students understand how theoretical knowledge is applied and improve their ability to solve engineering problems. Previous studies have explored project-based courses in new energy programs and strengthened the connection between classroom learning and engineering practice through real-world projects^[7].

Meanwhile, advances in digital technologies have provided new tools for energy and power engineering education. Some professional experiments involve complex equipment, processes that are difficult to observe directly, or limited experimental conditions. Virtual simulation and professional computational software have therefore been increasingly introduced into course teaching. Li et al. developed a virtual simulation platform and applied it to blended experimental teaching in fluid mechanics^[8]. The platform provided a more intuitive representation of experimental processes and supported students’ independent learning. Zhao et al. developed MATLAB-based virtual simulation software for the Rankine cycle^[9]. The software combined thermodynamic calculations with cycle performance analysis and expanded the content of Rankine cycle experiments. Hao et al. developed a virtual simulation experiment for heat-electricity analogy to address the limited flexibility and extensibility of conventional experiments. The system was subsequently applied to teaching in energy and power engineering^[10].

In response to the new requirements for energy and power engineering graduates arising from the development of new energy systems, this study carries out educational reform based on current undergraduate teaching practices. The reform focuses on course content, teaching resources, experimental and practical training, and student innovation activities.

2. Current problems in talent training for energy and power engineering

2.1. Limited alignment of course content with emerging energy technologies

Energy and power engineering has a strong practical and technical focus, and its course content needs to keep pace with developments in the energy industry. Current curricula are largely built around engineering

thermodynamics, heat transfer, fluid mechanics, and conventional energy conversion and utilization technologies, which provide the fundamental knowledge required for the discipline. However, course content has not always kept pace with the rapid development of hydrogen energy, energy storage, and smart energy technologies. Emerging technologies and recent engineering cases also need to be incorporated into classroom teaching more promptly.

In addition, emerging technologies are not well integrated across different courses. Some advanced topics are presented mainly as supplementary or standalone content, with limited connection to fundamental theories. Students may therefore understand basic theories and calculation methods but have difficulty applying them to new energy systems. This limits their ability to connect fundamental theories and professional knowledge with emerging energy technologies.

2.2. Limited use of research resources in undergraduate education

Energy and power engineering programs at universities generally have access to research platforms, research projects, and research outcomes. However, these resources are not fully utilized in undergraduate education. Research activities and classroom teaching remain somewhat separate in terms of content and implementation. Some research outcomes are primarily used for faculty research and have not been effectively transformed into teaching cases, experimental projects, or research topics suitable for undergraduate students.

The limited integration of research resources also affects the continuity of students' research training. Some students are first exposed to research activities through undergraduate innovation projects, academic competitions, or graduation projects, while opportunities for research practice in the early undergraduate years remain limited. The connection between research training and course learning is also insufficient, making it difficult for students to apply classroom knowledge to practical problems in a timely manner.

2.3. Insufficient continuity in practical and innovation training

Energy and power engineering has a strong practical orientation. Laboratory experiments, course projects, research training, academic competitions, industrial practice, and graduation projects are all important components of engineering training. However, these activities are often conducted separately in different courses or at different stages of undergraduate study, with limited connections among them. Outcomes from laboratory experiments and course projects are rarely carried forward into subsequent research training or engineering practice, resulting in a lack of continuity in practical training.

The depth of student participation also varies across practical activities. Some laboratory experiments still focus mainly on verifying fundamental theories and learning basic experimental methods, leaving students with limited opportunities to independently analyze problems, design solutions, and solve complex engineering problems. Connections among industrial projects, faculty research, and undergraduate practical teaching also need to be strengthened.

3. Reform measures for talent training in energy and power engineering

3.1. Updating of course content in response to advances in energy technologies

3.1.1. Updating course content in line with industry development

Course content provides the foundation for talent training reform. To meet the needs of new energy system

development and advances in energy technologies, emerging technologies such as hydrogen energy, energy storage, and smart energy are incorporated into the curriculum while retaining fundamental subjects such as engineering thermodynamics, heat transfer, and fluid mechanics. The integration points for emerging technologies are determined according to the knowledge structure and teaching objectives of each course. These technologies are linked with fundamental concepts, basic principles, and engineering applications rather than being presented simply as separate topics.

The connections among courses are further strengthened around the processes of energy production, conversion, transmission, distribution, and utilization. Course content related to modern energy systems, new energy, and energy storage is optimized, and new courses such as Hydrogen Energy Technology are introduced. A dynamic mechanism for updating course content is established to incorporate emerging technologies, advanced equipment, and representative engineering cases in response to technological advances and industrial needs. This approach enables students to understand recent developments and engineering applications in the energy sector while developing a solid foundation in professional theories.

3.1.2. Incorporating real-world engineering problems into classroom teaching

Closer connections are established between course content and engineering practice in the energy sector. Representative engineering problems are selected according to specific knowledge points. Topics such as energy equipment operation, system design, energy-saving analysis, and fault diagnosis are developed into classroom cases. Starting from fundamental principles, engineering problems are introduced to guide students through parameter calculations, performance analysis, solution comparison, and discussion of results. This approach enables students to apply their knowledge to explain and analyze practical engineering problems.

For more comprehensive topics, real engineering projects are appropriately simplified and divided into manageable tasks suitable for undergraduate students. Teaching is organized through a sequence of theoretical learning, case analysis, solution design, and result discussion. Students gradually progress from learning individual concepts to integrating knowledge from multiple courses to solve engineering problems, thereby strengthening the practical application of professional knowledge.

3.1.3. Integrating digital tools into professional teaching

Energy systems often involve complex operating processes, internal thermodynamic processes that are difficult to observe directly, and experiments that may be limited by available facilities. To address these issues, virtual simulation, professional modeling software, and digital course resources are integrated into classroom teaching. Virtual simulations are used to visualize internal processes and operating states of energy equipment. By varying parameters such as temperature, pressure, and flow rate, students can examine their effects on equipment and system performance. Simulation results are also compared with theoretical calculations to deepen students' understanding of professional knowledge.

The Ebsilon thermal system modeling tool is introduced into relevant courses for modeling, parameter setting, performance calculation, and operating analysis of typical thermal systems. Digital courses, including Engineering Thermodynamics and Heat Transfer, are developed to integrate theoretical instruction, virtual simulation, online exercises, and engineering calculations. By combining classroom teaching with digital resources, these tools are extended beyond supplementary learning and used directly for professional analysis and practical training.

3.2. Transforming research resources into undergraduate teaching resources

3.2.1. Transforming research outcomes into teaching cases

To strengthen the connection between research activities and undergraduate teaching, faculty research projects, academic publications, and related research outcomes are systematically reviewed. Research content that is closely related to course topics and appropriate for undergraduate students is selected and adapted for teaching. Rather than directly transferring research results into the classroom, key elements, including the engineering background, fundamental principles, research methods, and representative data, are extracted and redesigned as teaching cases according to course objectives. This approach connects research content with professional learning.

Research topics such as energy system optimization, enhanced heat transfer, pollutant control, and renewable energy utilization are incorporated into relevant courses. Case-based teaching follows the sequence of “identifying an engineering problem—analyzing fundamental principles—introducing research methods—discussing research results.” This process helps students understand how professional theories are applied in scientific research and engineering practice. It also introduces students to fundamental research methods and approaches through case analysis.

3.2.2. Using research platforms for experimental and innovation training

Research laboratories, research platforms, and advanced instruments are made available for undergraduate experimental teaching and innovation training. In addition to basic laboratory experiments, comprehensive, design-oriented, and research-oriented experiments are introduced at different stages of undergraduate study, with increasing levels of complexity. Junior students focus on experimental principles, measurement methods, and instrument operation. Senior students participate in research projects and conduct experimental design, data acquisition, result analysis, and performance evaluation.

According to the development of students’ abilities, practical training supported by research platforms is organized into four levels: basic experiments, innovation training, research practice, and engineering training. Specific training tasks and competency requirements are defined for each level. Open access to laboratories, guidance from faculty research teams, and student participation in research projects increase the use of research facilities in undergraduate education and provide opportunities for continuous and progressive practical training.

3.2.3. Transforming research projects into student research tasks

Research activities suitable for undergraduate participation are selected from faculty research projects and divided into manageable tasks with clear objectives. These tasks are incorporated into course projects, undergraduate innovation programs, academic competitions, and graduation projects. Under faculty supervision, students work on specific research problems through literature review, solution design, experimental testing or numerical simulation, data analysis, and result interpretation, allowing them to experience a relatively complete research process.

Connections among research tasks at different stages of undergraduate education are further strengthened. Problems identified during course learning can be developed into innovation projects, while research conducted through innovation training and research practice can be extended to academic competitions or graduation projects. This approach transforms isolated research activities into a progressive

learning process. By integrating faculty research projects with undergraduate education, students gain sustained opportunities to participate in professional research and solve practical problems, thereby improving their research and innovation capabilities.

3.3. Improving practical teaching to strengthen engineering and innovation capabilities

3.3.1. Establishing a progressive practical training process

To improve the connections among laboratory teaching, course projects, innovation training, academic competitions, and graduation projects, practical activities are systematically organized according to students' knowledge base and competency development. Training tasks are arranged in a progressive sequence of "basic experiments—comprehensive practice—innovation training—engineering application," with increasing levels of difficulty and complexity. Each stage has a specific focus while maintaining continuity with the preceding and subsequent stages.

In the early years, training focuses on basic experiments and professional orientation, with emphasis on standard experimental procedures, data processing, and experimental analysis. At the intermediate stage, comprehensive experiments and course projects are integrated with professional courses, enabling students to apply knowledge from multiple subjects to analysis and design tasks. In the senior years, innovation projects, research training, and graduation projects are used to address more complex professional problems through solution design, numerical simulation, experimental validation, and result analysis. This progressive arrangement reduces unnecessary repetition across practical activities and gradually strengthens students' practical capabilities.

3.3.2. Integrating academic competitions with professional learning

Academic competitions closely related to course content and disciplinary fields are selected according to the characteristics of energy and power engineering. Competition projects are used as an important platform for the integrated application of professional knowledge. Students work on specific competition tasks through literature review, solution design, model development, computational analysis, experimental validation, and presentation of results. This process enables them to integrate knowledge acquired from different courses to solve comprehensive problems.

Closer connections are established among academic competitions, course projects, innovation training, and research projects. Outcomes from coursework and research training can be further developed into competition projects. Competition projects with research or application potential can subsequently be extended into undergraduate innovation projects or graduation projects. This continuity prevents competitions from becoming isolated extracurricular activities and makes them an extension of professional learning and innovation training.

3.3.3. Strengthening industry-based engineering practice

To reduce the gap between university-based training and real engineering environments, representative engineering problems from industrial practice are incorporated into practical teaching. Students participate in activities related to energy equipment operation, energy-saving retrofits, system optimization, and operation and maintenance. These activities include on-site observation, operating parameter analysis, engineering calculations, and solution design, helping students understand the practical conditions and technical

requirements of professional knowledge in industrial applications.

Collaboration between universities and enterprises is further strengthened in practical teaching. Industry engineers are invited to participate in practical courses and supervise course projects and graduation projects. Real industrial projects, engineering cases, and technical requirements are incorporated into student assignments. Through joint supervision by university faculty and industry engineers, students gain a better understanding of equipment operating conditions, engineering design requirements, and safety standards while solving practical engineering problems. This process gradually improves their capabilities in engineering analysis, solution design, and practical problem solving.

4. Results of the educational reform

4.1. Improvement in course and practical teaching resources

Course content and digital teaching resources have been continuously improved in response to advances in energy technologies and talent training needs. Topics such as hydrogen energy, energy storage, and smart energy have been incorporated into professional courses. Six digital courses, including *Engineering Thermodynamics* and *Heat Transfer*, have been developed, together with knowledge graphs and supplementary teaching resources. Virtual simulation, Ebsilon thermal system modeling, and operational data from actual power plants have also been introduced into professional teaching, providing additional approaches for understanding complex energy systems and equipment operation. Practical teaching resources have also been strengthened. Research laboratories, instruments, and research projects have been increasingly made available for undergraduate education.

4.2. Significant improvement in students' practical and innovation capabilities

With stronger connections among research training, academic competitions, undergraduate innovation programs, and graduation projects, students have become more extensively involved in innovation and practical activities. Since the implementation of the reform, the participation rate in academic competitions and undergraduate innovation programs has reached 100%. Over the past four years, students have received more than 100 awards at the national and provincial levels in competitions such as the *Challenge Cup* and the *Internet+* Competition. More than 20 national and provincial undergraduate innovation projects have been approved. Under faculty supervision, students have also obtained 13 invention patents, published 8 SCI-indexed papers, and registered 7 software copyrights.

4.3. Steady improvement in postgraduate enrollment and employment outcomes

Students have maintained favorable outcomes in both postgraduate study and professional employment. Over the past three years, the postgraduate admission rates were 38.46%, 42.50%, and 43.42%, respectively, showing a steady upward trend. In each year, more than 64% of admitted students entered universities included in China's "Double First-Class" initiative. Graduates have been mainly employed by major enterprises such as State Grid, China Datang Corporation, and Weichai Power. Approximately 90% of graduates have secured employment in energy-related enterprises.

4.4. Continuous improvement in faculty teaching and course development

The reform of talent training has also promoted faculty development in teaching and course construction.

Through continuous efforts in course content renewal, digital resource development, and supervision of student innovation activities, the teaching team has developed two provincial-level first-class courses and one provincial-level demonstration course for curriculum-based ideological and political education. The team has also received provincial recognition for one high-quality national security education case and one exemplary labor education case. In addition, faculty members have led four undergraduate teaching reform projects in Shandong Province and five industry–university collaborative education projects supported by the Ministry of Education. They have published 18 papers on teaching and education research and authored four textbooks. In addition, Faculty members have also received multiple awards in the Shandong Provincial Young Teachers’ Teaching Competition, the Teaching Innovation Competition, and the National Blended Teaching Design Innovation Competition.

5. Conclusions

To meet the “dual carbon” goals and the needs of new energy system development, talent training in energy and power engineering needs to actively adapt to advances in energy technologies and changes in industry development. This study addresses the problems of insufficient connection between course content and emerging technologies, inadequate use of research resources in undergraduate teaching, and lack of continuity among practical teaching activities. Reforms were explored in three aspects: updating course content, transforming research outcomes into teaching resources, and reforming practical teaching.

Emerging technologies such as hydrogen energy, energy storage, and smart energy were integrated into professional courses. Research projects, experimental platforms, and research outcomes were transformed into teaching cases, innovation training projects, and graduation project topics. Meanwhile, stronger connections were established among experimental teaching, academic competitions, and engineering practice, thereby expanding the approaches available for students’ professional learning and practical training.

The results show that these reforms promoted the integration of classroom teaching, research training, and engineering practice. Students’ ability to apply professional knowledge, engineering practice capability, and innovation capability was improved. The reforms also promoted the development of course resources and faculty teaching capabilities. These practices can provide a reference for optimizing course teaching and practical training in energy and power engineering programs.

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Disclosure statement

The authors declare no conflict of interest.

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