

Discussion on the Reform of Undergraduate Education and Student Cultivation in the Field of Energy and Power Engineering

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Abstract: Against the backdrop of further-advancing Emerging Engineering Education and the development of new-quality productive forces, the energy and power industry is undergoing a critical transition, calling for more compound-type, innovation-oriented, and practice-focused professional talents. Undergraduate majors in energy and power engineering serve as the main position for cultivating high-quality engineering talents in the energy sector and the major supplier of talents required for energy transition and power-technology innovation. At present, undergraduate education and student-cultivation modes for energy-and-power-related majors in Chinese universities still suffer from problems such as curriculum systems lagging behind industrial development and imperfect practical-teaching systems. Traditional cultivation modes can hardly meet the development demands of the modern energy industry. Based on the philosophy of Emerging Engineering Education and actual industrial development, this paper analyzes the current status and major problems of undergraduate education and student cultivation for energy-and-power-related majors. Corresponding reform measures are put forward from the perspectives of curriculum-system reconstruction and teaching-mode innovation. It aims to improve and perfect the undergraduate talent-cultivation system for energy and power engineering, enhance students' engineering-practice capabilities, innovative abilities and career adaptability, and provide talent support and intellectual resources for the sound development of the energy industry.

Keywords: Energy and power engineering; Undergraduate education; Talent cultivation

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1. Introduction

Energy constitutes the main support for national-economic development, and power engineering serves as the fundamental cornerstone for industrial upgrading. The discipline of energy and power engineering is a key engineering major connecting three major fields: energy production, industrial application and technological innovation. It covers multiple directions, including thermal-energy engineering, power machinery, new-energy science and engineering, fluid machinery and engineering, and is widely applied in power generation,

high-end manufacturing, new-energy R&D, energy conservation and environmental protection, and other fields. With the continuous advancement of China's "Dual-Carbon" goal, the energy-production mode of the traditional energy and power industry is transforming from the coal-dominated traditional energy system to a new-generation energy system featuring multi-energy complementation, green low-carbon features and intelligence & high efficiency. Accordingly, higher requirements have been placed on the knowledge structure, engineering capabilities and comprehensive qualities of practitioners in the energy and power industry.

2. Current status of undergraduate education and student cultivation for energy and power engineering majors

2.1. Outdated curriculum systems

At present, most universities still take classic theoretical courses such as traditional thermal power generation, internal-combustion-engine principles and fluid mechanics as core courses for undergraduate energy-and-power-related majors. Their curriculum frameworks have not undergone systematic reconstruction for many years, resulting in problems of attaching importance to traditional contents while neglecting emerging contents and insufficient interdisciplinary integration. On the one hand, the updating speed of course contents falls far behind the technological upgrading of the industry. Contents of major emerging industrial technologies such as new-energy power generation, energy-storage technologies, hydrogen-energy utilization, intelligent-energy management and low-carbon energy-saving technologies can only be incorporated into teaching in the form of elective courses or lectures, rather than becoming core compulsory-course content. Students encounter difficulties in understanding and mastering these emerging technologies ^[1]. On the other hand, interdisciplinary integration is insufficient. The energy and power industry shows an obvious trend of intellectualization and digital transformation. Technologies such as artificial intelligence, big data, automatic control and digital simulation have been widely applied in engineering practice. Nevertheless, existing curriculum systems contain few integrated courses combining engineering fundamentals with information and intelligent technologies. Students possess a single knowledge structure and lack interdisciplinary capabilities to solve complex engineering problems. In addition, some courses suffer from drawbacks including duplicated content, redundant theories, and poor practicality. They place excessive stress on formula derivation and theoretical elaboration while providing insufficient explanations for practical engineering application scenarios, which decouples knowledge learned by students from actual industrial demands ^[2].

2.2. Rigid teaching modes

Current undergraduate teaching for energy and power engineering majors still mainly adopts traditional classroom teaching, relying on teachers' lectures and blackboard demonstrations for teaching activities, with insufficient application of information-based and intelligent teaching tools. Most teachers focus on imparting textbook content, ignore students' principal position, and lack interactive, inquiry-based and project-oriented teaching designs. Classroom atmosphere tends to be monotonous. Students passively receive knowledge with few opportunities for independent thinking and active inquiry ^[3]. A common phenomenon in teaching is the emphasis on theories rather than thinking. More attention is paid to the instruction and assessment of theoretical knowledge, while the cultivation of students' innovative thinking and engineering thinking is neglected. Cutting-edge industrial engineering problems are not integrated into teaching. The integration of ideological and political education into the curriculum lacks depth and systematicness. It fails to incorporate

the craftsman spirit of great nations in the energy industry, green-development concepts, and engineering-ethics norms into professional teaching, resulting in deficiencies in cultivating students' professional literacy and sense of responsibility. Such a rigid teaching ecology leads to low learning motivation among students, lack of innovative spirit, and incapacity to independently analyze and solve problems ^[4].

2.3. Imperfect practical-teaching systems

Practical teaching constitutes a vital stage for the growth of engineering talents majoring in energy and power engineering and exerts a direct influence on students' engineering-practice capabilities. However, practical-teaching systems in most universities have obvious defects. Experimental-teaching content is outdated. Current experimental projects are mainly confirmatory and basic experiments, with insufficient innovative, comprehensive and design-oriented experiments. Students can only conduct experimental operations following preset procedures. They cannot independently design experimental schemes or tackle unexpected problems arising in experiments, and cannot develop engineering-practice and innovative-design capabilities ^[5]. The quality of internships and practical training is low. Universities have a small number of off-campus internship bases with shallow-level cooperation. Most enterprises only allow students to observe and study without providing practical-operation posts. Post-internship and project-oriented practical training become superficial formalities. Meanwhile, the renewal of on-campus practical-training equipment lags behind the times. Many outdated devices are still in use, which fall short of the technical standards of state-of-the-art industrial equipment. Practical-training content for students on campus differs greatly from real-world enterprise-production scenarios. The proportion of practical-teaching class hours is relatively small. Some universities cut practical-teaching hours to shorten teaching cycles, leaving students with inadequate time for hands-on practice and hindering the improvement of their engineering-application capabilities ^[6].

3. Reform countermeasures for undergraduate education and student cultivation of energy and power engineering majors

3.1. Reconstruct modular and cutting-edge-oriented curriculum systems based on industrial transformation

Based on the Dual-Carbon Strategy and the transformation demands of the energy industry, and oriented toward the talent-cultivation objectives of Emerging Engineering Education, existing curriculum systems shall be systematically reconstructed to build a modular curriculum system featuring solid fundamentals, prominent cutting-edge contents, interdisciplinary integration and industrial adaptability ^[7]. First of all, optimize the basic-course module. Retain major basic courses including engineering mechanics, fluid mechanics, heat transfer, and engineering thermodynamics; remove outdated and duplicated theoretical content; strengthen explanations on the engineering applications of basic theories; and consolidate students' foundational knowledge. Secondly, update the professional-core-course module. Add state-of-the-art industrial content concerning new energy, low-carbon energy conservation, and intelligent power. Set up core courses such as new-energy power-generation technologies, principles and applications of energy storage, hydrogen-energy power technologies, intelligent control of energy systems and low-carbon engineering technologies. Phase out old course contents disconnected from industrial development to realize synchronization between course contents and industrial-technological progress ^[8].

In addition, build interdisciplinary integrated course modules. In response to the intelligent and

digital-transformation trend of the energy industry, add interdisciplinary courses such as big-data-based energy analysis, intelligent-control technologies, engineering simulation, and engineering applications of artificial intelligence on the basis of existing courses. Break disciplinary barriers and cultivate students' interdisciplinary thinking and comprehensive-application capabilities^[9]. Moreover, set up elective-course modules oriented toward regional energy-industrial characteristics and students' development. Construct characteristic professional-course groups covering optimization of thermal power generation, energy-saving technologies for refrigeration and air-conditioning, and design of new-energy equipment, so as to realize students' all-round development and satisfy talent demands for segmented posts in various industries^[10].

3.2. Innovate teaching modes and build diversified intelligent teaching systems

Break the shackles of traditional rigid teaching modes, and leverage information-based teaching platforms to create new and more flexible teaching modes: diversified intelligent teaching modes that integrate online and offline learning, connect theoretical learning with inquiry-based activities, and combine classroom lectures with project assignments. Promote classroom-teaching reform, abandon the traditional cramming lecture mode, and widely adopt new teaching approaches such as flipped classroom, project-oriented teaching, case-based teaching and group-inquiry teaching. Design teaching contents based on real-world engineering projects and cutting-edge technical challenges in the energy industry to motivate students to think actively and conduct independent inquiry, and give play to students' principal status in teaching^[11]. Secondly, strengthen the application of information-based teaching. Integrate high-quality online teaching resources and build online-learning platforms. Incorporate micro-lectures, simulation videos, cutting-edge lectures and engineering-case libraries into daily teaching to realize full-process intelligent teaching covering pre-class preview, in-class interaction and after-class expansion, and make up for deficiencies in classroom teaching^[12].

Meanwhile, advance the construction of curriculum-based ideological and political education. Take cognition, responsibility, and action as the main thread, and dig out ideological and political elements contained in professional courses of energy and power engineering. Integrate green-development concepts, missions of the Dual-Carbon Strategy, craftsman spirit of great nations, engineering-ethics norms and energy-security responsibilities into the whole process of professional teaching, so as to realize the unification of knowledge imparting, competence cultivation and value guidance. In addition, encourage teachers to combine scientific-research projects with teaching, transform the latest scientific-research achievements into teaching cases and materials, and promote teaching development via high-level scientific research. In this way, students can gain access to cutting-edge industrial scientific-research information, and their innovative thinking and scientific-research capabilities can be stimulated.

3.3. Improve practical-teaching systems and strengthen students' engineering-practice capabilities

Focusing on improving students' engineering-practice capabilities, build a four-level progressive practical-teaching system of "basic experiments — comprehensive practical training — innovative practice — engineering practice", so as to thoroughly overcome shortcomings in practical talent cultivation. First of all, optimize experimental-teaching contents. Reduce the proportion of basic and confirmatory experiments, and increase the proportion of comprehensive, design-oriented and innovative experiments. Cultivate students' capabilities to independently design experimental schemes and operation procedures and solve technical problems occurring in experiments, so as to improve their practical-operation and innovative abilities^[13].

Meanwhile, upgrade on-campus practical-training equipment. Update laboratory facilities for thermal experiments, power simulation and new-energy practical-training in accordance with advanced industrial technologies and equipment standards, and build intelligent and modern practical-training platforms to ensure that practical-training contents are in line with real-world industrial practice.

Secondly, improve the quality and efficiency of off-campus internships and practical training. Expand high-quality school-enterprise-cooperation internship bases, and establish long-term and stable partnerships with power-generation groups, new-energy-technology enterprises and power-equipment manufacturers. Transform internships from “observation-oriented” to “practice-oriented”, allowing students to take part in production projects, technological transformation, equipment operation & maintenance and other work on front-line enterprise posts and accumulate hands-on engineering-practice experience. When adding practical links such as course design, engineering practical training and graduation projects, put forward targeted requirements for guidance work. Graduation projects and course designs must be associated with real-world enterprise-engineering-project problems, and formalistic and hollow designs shall be avoided.

3.4. Deepen industry-education integration and build a long-term school-enterprise collaborative talent-cultivation mechanism

Based on industrial demands, promote in-depth industry-education integration, break barriers in school-enterprise talent cultivation, and establish a long-term collaborative-cultivation mechanism featuring “joint construction by schools and enterprises, resource sharing, whole-process co-cultivation and joint quality evaluation”. First of all, ensure that enterprises genuinely participate in every link of talent cultivation. From talent recruitment to the whole talent-cultivation process (including talent evaluation), invite enterprise technical backbones and industrial experts to join professional-teaching-guidance committees to deliberate on major decisions, including talent-development plans, teaching plans, curriculum setting, internships & practical training, and employment guidance. This guarantees that talent-cultivation objectives, course contents and practical links fully match enterprise post requirements ^[14]. Secondly, promote joint construction and sharing of school-enterprise resources. Schools and enterprises co-build practical-training bases, engineering-research centers and innovation studios. Integrate teaching & scientific-research resources of universities and production-technology resources of enterprises, and incorporate real-world enterprise-engineering projects and cutting-edge technical cases into classroom teaching, so as to realize seamless connection between teaching contents and production practice.

At the same time, promote the cultivation of double-qualified teachers. On the one hand, support on-campus teachers to take temporary posts in front-line enterprises to accumulate hands-on engineering experience and enhance their capabilities in practical-training teaching for students. On the other hand, introduce senior enterprise technical backbones to serve as part-time teachers in universities, who shall be responsible for practical teaching, case lecturing, and practical training tutoring, so as to make up for the deficiency of practical engineering experience among on-campus teachers ^[15]. In addition, establish long-term guarantee systems for school-enterprise collaborative cultivation, clarify mechanisms concerning educational responsibilities of both sides, resource input and achievement distribution, standardize cooperation procedures, ensure regular, systematic and in-depth development of school-enterprise cooperation, and realize synchronized development of talent cultivation and industrial demands.

4. Conclusion

Undergraduate talents majoring in energy and power engineering constitute an important foundation supporting China's energy transition, industrial upgrading and implementation of the Dual-Carbon Strategy. Against the background of Emerging Engineering Education and the development of new-quality productive forces, traditional teaching and talent-cultivation modes must be innovated and upgraded. In the future, universities offering energy-and-power-related majors shall keep pace with technological updates and industrial upgrading in the energy industry. Centering on the requirements of Emerging Engineering Education teaching reform, they shall continuously strengthen reform and innovation of teaching and talent-cultivation modes, dynamically adjust course contents, teaching methods and educational mechanisms, keep promoting industry-education integration as well as research-teaching integration, and improve the quality and standard of talent cultivation. They shall continuously cultivate high-quality professional talents for the high-quality development of China's energy industry and the construction of new-type energy systems, and boost the transformation, upgrading and green development of industries.

Disclosure statement

The author declares no conflict of interest.

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