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Research on the Reform of Professional Skill Training in Architectural Environment and Energy Application Engineering: A Case Study of Shandong University of Petroleum and Chemical Technology

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Abstract: The Architectural Environment and Energy Application Engineering program aims to cultivate versatile engineering technology professionals, and internship education plays a crucial role in bridging theory and practice. Taking the Architectural Environment and Energy Application Engineering program at Shandong University of Petroleum and Chemical Technology as a case study, this paper analyzes the issues encountered in internship training. In response to these challenges, three improvement measures are proposed. First, virtual simulation scenarios are integrated with BIM (Building Information Modeling) software training, reinforcing overall system understanding through the combination of "training reports + BIM models." Second, a card model-making project is introduced to enhance students' hands-on skills and teamwork through group collaboration, with a comprehensive assessment approach combining "model evaluation + defense." Third, external internship bases are expanded, with the addition of the Shengli Oilfield New Energy Center, covering seven major projects, including photovoltaic and waste heat recovery. By constructing a dual-track training system of "traditional HVAC + new energy low-carbon" in parallel, the fragmentation of practical training and the disconnect between theory and practice are effectively addressed.

1. Introduction

The Architectural Environment and Energy Application Engineering program is a highly applied discipline, with the goal of training professionals who possess the foundational theoretical knowledge and specialized skills required for technical work in this field. Graduates are expected to engage in roles such as design research, engineering construction, equipment manufacturing, and operation management in enterprises or institutions involved in heating, ventilation, air conditioning, purification, thermal and cooling sources, heating supply, and gas systems[1]. These roles include planning and design, research and development, manufacturing, installation, operation management, and system support, across both technical and management positions. The program covers technologies related to heating, air conditioning, refrigeration, ventilation, and gas systems.Internship education serves as a key bridge between theoretical knowledge and practical engineering applications, playing an irreplaceable role in cultivating students' practical abilities, innovative thinking, and professional technical competence in solving real-world problems. Through internships, students are able to integrate classroom knowledge with actual engineering projects, gaining a deeper understanding of industry development trends, and better preparing themselves to meet the demands of future job positions, thereby achieving the goal of training versatile engineering technology professionals.

However, compared to research on course instruction, research on practical teaching remains relatively underdeveloped and lacks depth[2]. This paper will focus on the issues encountered in the reform of the professional skill training courses in the Architectural Environment and Energy Application Engineering program at Shandong University of Petroleum and Chemical Technology, with the aim of addressing the current shortcomings in the course support process.

2. Problems in Professional Skills Training and Teaching

In the internship process of the Architectural Environment program, students are required to understand and familiarize themselves with the practical sites and equipment. However, issues such as a lack of diversity in internship formats and insufficient development of internship bases exist during the arrangement and execution of the internship[3-5].

(1) The number of students participating in internships is large, but the internship formats are limited. Since 2017, the Architectural Environment program has enrolled two classes each year, with around 60 students participating in production internships. Typically, 3-4 instructors are assigned to guide the internships each year. The previous training mainly consisted of instructors leading students to visit construction sites or conduct experiments in laboratories, allowing them to understand and familiarize themselves with refrigeration and air conditioning systems and equipment. Due to the large number of students, and the high noise levels and complex environments at construction sites, most students are unable to hear the explanations clearly, only acquiring superficial knowledge. They fail to gain in-depth understanding of related structures or principles. Moreover, students are in a passive learning state during the internship, making it difficult for them to form a holistic understanding. The internship format is monotonous, and most of the internship process is not directly related to practical applications. Repetitive on-site explanations lead to student fatigue. Students show little interest in the processes and practical applications of HVAC systems, lack critical thinking about actual engineering projects, and are unable to meet the expectations.

(2) The internship duration is relatively short, and students have limited opportunities to participate in practical training. The professional skill training is scheduled in the seventh semester, by which time students have not yet been exposed to much specialized knowledge. At the site, they are only aware of some equipment and a large number of pipes, but they do not understand the purpose of the equipment or pipes, nor do they have an understanding of the system composition, making it difficult for them to form a complete picture of the system. Moreover, since most air conditioning systems are hidden systems, it is difficult to observe the internal installation and terminal equipment. According to the curriculum plan for the Architectural Environment program, the training lasts for only 4 weeks. For the receiving internship organizations, 4 weeks is a short period, typically allowing students only to familiarize themselves with the basic conditions of the site and learn some basic construction or production processes by shadowing experienced workers. Students cannot directly engage in practical

exercises or take on full-time tasks, so their hands-on skills are not adequately developed.

(3) There are few local internship organizations, and they are unable to cover the full scope of the training objectives for the Architectural Environment program. Due to limited funding for internships, the school can currently only conduct internships in Dongying (the location of the university). Local enterprises are mostly concentrated in the petroleum and petrochemical sectors, which can provide internship and practical training opportunities in areas such as heating, thermal supply, and gas systems. However, there is a lack of corresponding training organizations in fields like air conditioning, purification, thermal and cooling sources, and refrigeration. All organizations place a strong emphasis on safety production, with safety responsibilities assigned to each individual. Supervisors are concerned that students might cause safety accidents by carelessly handling equipment, which makes them reluctant to accept students for internships. Additionally, some organizations, especially those in the service industry, are worried that hosting interns might interfere with their normal operations, making it difficult to establish internship placements.

(4) The quality of instructors at the internship organizations varies. Typically, internship organizations assign staff members to provide explanations, enabling students to learn a great deal from the site. However, some instructors are unable to explain clearly to the students, while others either do not understand the students' characteristics or overestimate their abilities. As a result, the focus of the explanations differs, and students are unable to fully grasp the content being taught.

3. Improvement Methods for Internship Teaching

The university has established a Virtual Simulation Laboratory for Architectural Environment and Energy Utilization, which is equipped with a local area network and over 20 new computers, enabling network simultaneous transmission, teacher-student interaction, and other management functions[6]. Additionally, the laboratory is equipped with multimedia projectors, allowing for virtual simulation software that supports both indoor and outdoor HVAC scene roaming. The laboratory also has BIM-related engineering software, enabling both virtual simulation internships and software training. The HVAC scene roaming software covers core scenarios such as residential buildings, public buildings, and industrial buildings. Each scenario includes three functional modules: "Equipment Disassembly," "Process Animation," and "Fault Simulation," supporting students in viewing the pipeline layout and internal structure of equipment in 360 °, with parameters such as pipe diameter, equipment model, and operational efficiency displayed when clicking on components.

Previously, the HVAC scene roaming simulation and BIM software training were conducted separately by two different instructors, which led to students only skimming through the scene roaming training, focusing mainly on the layout of the HVAC pipelines while neglecting the functions of the various pipes and equipment, thus failing to gain a comprehensive understanding of the HVAC system. During the BIM software training, students only learned basic operations, and the case studies remained superficial.

As part of the reform, the scene roaming training and BIM software training have been integrated. Instead of submitting a training report, students now submit both a "training report + HVAC system BIM diagram." In the scene roaming training, the instructor focuses on guiding students through the roaming operations and explaining the principles of the equipment. In BIM software training, the emphasis is not only on basic operations but also on instructing students on how to recreate the HVAC system using BIM software. Additionally, students are encouraged to complete tasks in groups. The assessment includes four core components: thermal and cooling sources (e.g., chiller units, boilers), distribution systems (e.g., pipes, pumps, fans), terminal equipment (e.g., fan coil units, air outlets), and control components (e.g., valves, thermostats). The pipe labeling is clear, including pipe diameter and material, and the equipment parameters align with the scene roaming software (e.g., fan coil unit model, cooling capacity), meeting the modeling standards.

The Cardboard Model approach from Nanhua University[7] is applied to the on-site training project, where various pieces of equipment in the training room are recreated. This method enhances students' teamwork awareness, participation, and understanding of the equipment. At the same time, advanced system testing tools are introduced to deepen students' understanding of system faults, assisting them in completing the cardboard model. Students work in groups, following tasks assigned by the instructor. They use cardboard to create exterior models of various equipment or components, to form an HVAC model system that can represent the system's workflow. During the assessment phase, students present and explain their models. Each group consists of 6-8 students with clearly defined roles (e.g., "data collector" responsible for gathering equipment parameters, "designer" responsible for drawing the model sketch, "fabricator" responsible for cutting and assembling the cardboard, and "presenter" responsible for preparing the defense presentation). Before the internship, the instructor distributes cardboard, scissors, glue, and markers (for labeling equipment names and process arrows), while each group prepares rulers and compasses (for proportion measurements).

The cardboard model-making process requires students to cut the cardboard according to the sketch and create core equipment (such as compressors, condensers, evaporators, fans, ducts, valves, air filters, etc.), ensuring neat edges on the components. They label critical parameters on key equipment (e.g., heat exchange area on the evaporator). The instructor intersperses explanations of equipment manufacturing processes (such as the bending process of copper tubes for condensers, or the jointing technique for ducts) and compares them with actual engineering construction requirements, addressing challenges in the model-making process (such as the sturdiness of cardboard joints). If issues such as proportional imbalance or loose components arise, the group collaborates to find solutions (e.g., reinforcing loose parts with double-layered cardboard), with timely guidance from the instructor.

Table 1: Seven major projects of the New Energy Center.

Serial Number	Training Projects	Core Professional Competencies
1	Solar Photovoltaic Power Generation Project	Photovoltaic Panel Installation Layout, Photovoltaic - HVAC Integrated System
2	Waste Heat Utilization Project	Operating Principles of Industrial Waste Heat Recovery Devices (e.g., Heat Exchangers, Heat Pump Units)
3	Geothermal Development Project	Geothermal Well Heat Exchange System, Geothermal Heating / Cooling Process
4	Solar Thermal Applications Project	Solar Collector and Building Heating Integration System
5	Multi-source Microgrid Project	New Energy and Traditional Energy Complementary Power Supply / Energy Supply System Regulation
6	Air Source Heat Pump	Heat Pump Operating Efficiency Testing under Different Climate Conditions, Frost Prevention and Control Technologies
7	Clean Carbon Reduction Monitoring Project	Carbon Emission Measurement and Energy Efficiency Benchmarking Analysis of New Energy Systems

Through this process, students gain a qualitative improvement in their understanding and mastery of professional equipment and systems, while also expanding their knowledge in areas such as manufacturing processes and cutting-edge engineering technologies. This approach broadens their horizons, cultivates teamwork and mutual assistance, and improves skills in literature research and communication. The assessment for the training project is divided into two parts: "model evaluation" and "defense evaluation." The model evaluation accounts for 60% of the score, and the group defense evaluation accounts for 40%. The model is evaluated based on completeness, proportion, and process expression, with scores given by 2-3 instructors. The defense is evaluated based on the logical structure of the explanation, understanding of principles, and collaboration, with full participation from the group.

The university aims to strengthen the construction of internship bases and focus on cultivating students' practical skills. Building on the existing internship bases (such as the gas company, central heating exchange stations, and geothermal heat pump demonstration bases), the Architectural Environment program has added an off-campus training base at the Shengli Oilfield New Energy Center. This new center includes seven major projects: solar photovoltaic power generation, waste heat recovery, geothermal energy, solar thermal energy, multi-source microgrids, and air-source heat pumps (Table 1). These projects are closely related to the clean carbon reduction direction of the program, providing students with valuable opportunities to broaden their horizons.

4. Conclusions

This training program integrates the traditional internship bases, such as the gas company and heat exchange stations, with the newly added Shengli Oilfield New Energy Center, creating a dual-track training system of "traditional HVAC + new energy low-carbon" that simultaneously strengthens students' understanding of classical HVAC systems while expanding their practical skills in the clean carbon reduction field, in line with the "dual carbon" strategy. The program forms a closed-loop knowledge transfer chain, starting from off-campus bases with "cognitive observation + hands-on analysis," to on-campus virtual simulations with "parameter simulation + model verification," and then to physical model creation with "element integration + comparative explanation." This structure effectively breaks the limitations of past fragmented training and the disconnect between theory and practice.

Through a multi-dimensional output of results, including "training reports + BIM models + new energy components," and a comprehensive evaluation system, this program not only thoroughly assesses students' overall mastery of HVAC systems but also stimulates their innovative thinking in system optimization and the application of low-carbon technologies. In the future, this integrated training model will continue to deepen industry-education collaboration, relying on real engineering scenarios from bases such as the Shengli Oilfield New Energy Center. It will continuously update training content and upgrade teaching methods, helping the Architectural Environment program cultivate interdisciplinary talents who are proficient in both traditional HVAC technologies and the integration of new energy applications, with a strong foundation in green engineering. This will contribute to the industry's low-carbon transformation and high-quality development, providing solid support for the sector.

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