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REVIEW ARTICLE

Practical exploration of the multi-functional integrated development of virtual simulation teaching platforms in the oil and gas industry

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ABSTRACT

The comprehensive reform of China's education system continues to deepen, with growing prominence placed on new demands for practical education, exemplified by labor education and science popularization. Exploring how traditional practical teaching platforms can better align with increasingly diverse and integrated educational needs has become a key focus in the latest round of practical teaching reform. Taking the virtual simulation teaching platform for the oil and gas industry as a case study, this research systematically elaborates on innovative concepts for the development of traditional practical teaching platforms. The core approach involves moving beyond a singular teaching function to establish a multi-functional, integrated development model. This model centers on practical teaching, is supported by professional labor education, and extends through science popularization services and social engagement. Practice has demonstrated that this model not only significantly enhances the effectiveness of engineering practical education and promotes comprehensive improvements in the teaching quality of core disciplines but also offers valuable insights into addressing challenges such as the disconnect between labor education and professional practice, the underutilization of practical resources in higher education institutions, and the limited scope of social service functions.

Keywords: practical teaching platform, multifunctional integration, labor education, science popularization

INTRODUCTION

As a pivotal force supporting national energy security and the realization of "Dual Carbon" goals, energy-oriented higher education institutions play a critical role whose quality of talent cultivation directly influences the transformation, upgrading, and innovative development of the energy industry (Wang et al., 2021). However, for a long period, key practical teaching links—such as professional and production internships—have often been relegated to formalities due to constraints like high-risk scenarios, complex processes, and spatial limitations at internship sites. This has led to inconsistent outcomes in fostering students' engineering practical abilities and innovative potential (Li et al., 2023; Zhao et al., 2022). The rise of digital technologies, such as virtual simulation and 3D modeling, has opened effective paths to overcome these dilemmas in practical education (Wu et al., 2018; Pallanich, 2025). Consequently, diverse virtual simulation practical teaching centers and platforms have emerged, gradually becoming the primary venues for practical teaching in energy-related universities (Yang et al., 2020;

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Wang et al., 2019; Liu et al., 2017).

In the new era, with the continuous deepening of China's comprehensive educational reform, structural changes have occurred in both internal and external demands for higher education. On one hand, policy documents such as "Opinions on Comprehensively Strengthening Labor Education in Universities, Primary, and Secondary Schools in the New Era" explicitly require integrating labor education throughout the entire talent cultivation process to enhance the competency-breeding function of practical links (Qu & Liu, 2019; Liu, 2018; Zhong, 2021). On the other hand, the strategic orientation of "integrated innovation and science popularization" demands that university practical teaching platforms possess the dual attributes of professional education and public service (Xie et al., 2023; Lin et al., 2020).

Against this backdrop, integrating discrete experimental teaching resources, breaking down the barriers between "practical teaching, labor education, and science popularization," and constructing a "functional fusion" practical teaching platform to meet the new demands of higher education has become an urgent task. To this end, focusing on the disciplinary characteristics of the oil and gas industry and leveraging high-quality resources such as national "First-Class Majors" and "First-Class Courses," the university has systematically constructed the "Oil and Gas Industry Virtual Simulation Practical Teaching Platform," covering the entire industry chain. While efficiently supporting professional practical teaching, the platform incorporates modules for labor spirit cultivation and energy science education, forming a new "trinity" functional model of "Professional Practice - Labor Education - Science Popularization Services," which has achieved significant pedagogical results and social impact.

RESEARCH STATUS AND EXISTING PROBLEMS

Practical teaching is the critical link for engineering majors—such as Petroleum Engineering, Resource Exploration Engineering, Chemical Engineering and Processes, and Mechanical Design, Manufacturing and Automation—to bridge theory and industry. However, traditional practical teaching faces a long-standing "safety dilemma": enterprises are often reluctant to host students due to safety and production pressures. Even when accepted, students' operational permissions are strictly limited, leading to superficial "sightseeing" internships with low engagement and minimal educational gains.

Virtual simulation technology provides key technical support to break this deadlock, evolving from "decorative assistance" to "systematic integration" (Rostova et al., 2023; Xiong, 2020). High-fidelity simulation scenarios not only enhance students' operational skills, innovative thinking, and ability to solve complex engineering problems but also implicitly reinforce cost control and safety awareness. However, research within the oil and gas sector indicates that existing virtual simulation content often exhibits fragmented characteristics of "isolated segments and decentralized layouts." Platforms tend to focus either on upstream exploration, midstream transportation, or downstream refining, lacking a systematic integration of the entire "Geology–Drilling–Production–Gathering & Transportation–Refining" chain. This fragmentation hinders students from forming a holistic understanding of industrial processes and systematic thinking, thereby restricting the leap in their comprehensive engineering practical abilities (Lu et al., 2021).

Furthermore, practical teaching follows cyclical patterns, leaving facilities and equipment idle for long periods after scheduled tasks, resulting in a structural waste of resources. Simultaneously, the social service functions of university laboratories are often confined to highly specialized research projects, lacking universal public services for the general population. In contrast, primary and secondary schools—the frontiers of science and culture dissemination—face challenges such as lagging knowledge systems, vague career planning for students, and a shortage of high-end teaching resources (Zhang et al., 2025). As hubs of intellectual height and original technological innovation, universities should shoulder the mission of promoting the synergistic development of science and innovation education across different educational stages. Extending the functions of practical platforms to science popularization is a significant measure for reshaping the social service role of higher education (Wang et al., 2020). Unlike traditional key laboratory openings and science lectures, virtual simulation platforms, by virtue of their immersive and interactive characteristics, can transform science popularization education from "watching" to "doing," and from "passive reception" to "active exploration," thereby achieving cross-stage integration and inclusive sharing of high-quality educational resources in a more penetrating manner. In recent years, fields such as aerospace, chemical engineering, and civil engineering have successively carried out science popularization work relying on virtual simulation laboratories, accumulating considerable practical experience and forming distinctive science popularization paradigms (Long et al., 2021). In contrast, exploration in the oil and gas industry in this regard remains relatively slow, with systematic and normalized science popularization practices still lacking.

Labor education constitutes an important component of the socialist education system with Chinese characteristics and holds unique strategic value in university talent cultivation. For college students who are in the critical transition stage from learning to work, authentic labor practice can deepen their understanding of the connotation of labor, establish a conscious connection between professional learning and the world of work, enhance career awareness and professional mission, and thereby facilitate high-quality employment and career development. In recent years, labor education in universities has gradually moved from conceptual advocacy to practical exploration (Liu et al., 2020). Some universities have established institutional frameworks by introducing compulsory courses and incorporating labor education into training programs, and have integrated labor education into internship training, professional services, innovation, and entrepreneurship through university-industry cooperation bases, science and technology parks, and logistics service sites. However, in practice, structural challenges remain. On the one hand, labor education often remains at the level of contrived scenario simulations, with content that is markedly homogeneous with labor education in primary and secondary schools, showing a pronounced tendency toward manual labor, and lacking authentic, professionalized experiences that align with modern industrial systems (Xu, 2022). On the other hand, labor education has failed to effectively connect academic studies, career preparation, and professional calling. After participating in labor practice, students still have a vague understanding of the career prospects of their majors and the competencies required by the industry. The methods and content of labor education are disconnected from the high-quality talent demands of enterprises, making it difficult to truly achieve the three-dimensional cultivation goal of "grounding in academic studies, progressing through career preparation, and aspiring to a professional calling."

CONSTRUCTION OF THE VIRTUAL SIMULATION PLATFORM FOR THE OIL AND GAS INDUSTRY

The platform's construction deeply integrates modern information technologies such as 3D modeling, Virtual Reality (VR), and human-computer interaction to create a full-process immersive environment. It simulates real equipment, processes, and control systems while innovatively embedding multi-dimensional training modules for dynamic parameter adjustment, fault simulation, and safety assessments. This achieves a graduated capacity-building model—from cognitive internship and simulated operation to innovative design—within a low-risk, repeatable environment. (Figure 1)

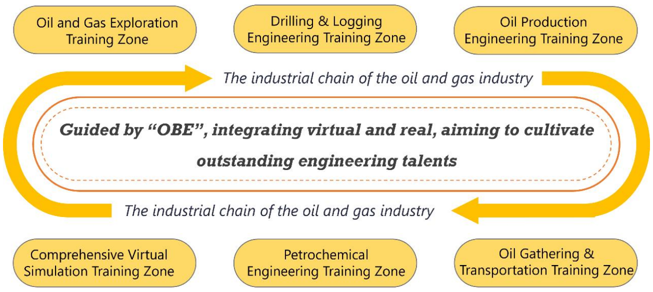

Figure 1. Construction Zones of the Oil and Gas Industry Virtual Simulation Practical Teaching Platform

Oil and gas exploration training zone

The Oil and Gas Exploration Training Zone is strategically organized around core disciplines such as petroleum geology and geophysical well logging. It comprises three teaching units: Mineral and Rock Training, Comprehensive Geological Exploration Practice, and Well Logging Method Training. The Mineral and Rock Training teaching unit displays over 700 specimens, including rock-forming minerals, three major rock types (igneous, sedimentary, and metamorphic), and fossil remains. Concurrently developed digital resources enable a clear demonstration of mineral characteristics—crystal morphology, color, luster, and transparency—as well as rock features such as color, texture, structure, and composition, from both macroscopic and microscopic perspectives. The Comprehensive Geological Exploration Practice Platform uses physical cores and digital core models as its primary carriers, covering physical core samples and digital resources from major petroliferous basins across China. This platform supports training in various subjects, including core fracture analysis, mineral type identification, mineral content determination, single-well core description, and lithologic column drawing. The Well Logging Method Training unit employs an integrated intelligent well-logging truck (physical vehicle) and an FMI well-logging virtual simulation training project as teaching carriers. Through a combination of virtual and physical methods, it reproduces the well-logging workflow and equipment operation. This unit supports training projects such as well-logging tool recognition, tool placement (lowering), and simulated logging (FMI), thereby fully cultivating students' engineering practice abilities.

Drilling and logging engineering training zone

The Drilling and Mud Logging Engineering Training Zone are modeled on the top-drive drilling rig. By integrating technologies such as automation control, intelligent sensing, virtual simulation, and 3D synchronization, it comprises two teaching units: the Drilling-Well Control Simulation Training Platform and the Mud Logging-Well Control Simulation Training Platform. Using the Drilling-Well Control Simulation Training Platform, students can first gain a preliminary understanding of the wellsite layout, main components of the drilling rig, well control equipment, solids control equipment, and manifold installation. Subsequently, through team-based collaboration, they engage in hands-on training on equipment such as the disc brake console, remote choke panel, blowout preventer (BOP) control console, BOP remote control station, choke manifold, and kill manifold. Finally, they complete virtual simulation training in drilling well control and downhole incident handling. The Mud Logging-Well Control Simulation Training Platform enables training in the disassembly, assembly, and operation of mud logging sensors, gas detection, mud logging signal acquisition and analysis, and the use of comprehensive mud logging units through simulation operations combining virtual and physical elements. Alongside hands-on training, a software system integrating the functions of "learning, practicing, assessing, and evaluating" is employed to monitor, record, and evaluate the entire operation process, thereby enhancing students' ability to perform standardized operations.

Oil production engineering training zone

The Oil Production Engineering Training Zone focuses on oil and gas injection-production technology and downhole operation tools. It is equipped with physical and simulation training devices, including self-flowing wells, beam pumping units, belt-type pumping units, electric submersible pumps, progressive cavity pumps (PCPs), water injection wells, metering stations, and wellbore structure models. Based on this equipment, an integrated central control console enables coordinated control of each injection-production unit, realistically reproducing the process logic and operating environment of an oilfield production site. The training projects cover cognitive and hands-on training in key process links, including equipment structure recognition, pumping unit start-up and shutdown, manual oil and gas metering, dynamometer card and current card interpretation, production data regulation and analysis, surface wellhead fault diagnosis, and instrument maintenance and replacement. The supporting physical devices—such as whole-barrel pumps, progressive cavity pumps, packers, and various downhole tools—provide favorable conditions for students to learn equipment structures and conduct disassembly/assembly practice. This achieves a full-process integration from virtual simulation to physical operation, and from principle cognition to skill training, effectively enhancing students' comprehensive competence in solving field engineering problems.

Oil and gas gathering and transportation training zone

The Oil and Gas Gathering and Transportation Training Zone is built around the process flow and actual production of oil and gas storage and transportation. It comprises multiple simulation training units, including a central processing station, long-distance crude oil transmission, long-distance natural gas transmission, and an LNG receiving terminal. Each unit, modeled on real production scenarios, supports comprehensive training functions such as process equipment cognition and operation, production data regulation and optimization, abnormal condition diagnosis and response, alarm response and early warning decision-making, risk identification and hazard elimination, emergency accident drills, digital twin applications, and innovative practice. Specifically, the central processing station simulation platform is designed according to the oil-gas-water treatment process, integrating gathering manifolds, three-phase separators, crude oil stabilization towers, etc. It focuses on simulating the dynamic characteristics of oil and gas treatment processes and revealing the influence mechanisms of process parameters on treatment efficiency and product quality. The long-distance crude oil transmission simulation platform is divided into a starting station, intermediate stations, and a terminal station based on the pipeline system structure. It is equipped with simulation hardware such as external floating roof tanks, heating furnaces, heat exchangers, and gas detectors. Key tanks are paired with 3D condition simulation interactive controllers to achieve dynamic visualization of internal equipment structures and to simulate normal and abnormal operating conditions based on real-time operational data. The long-distance natural gas transmission simulation platform covers simulation modules for separators, air coolers, compressors, and instrument valves, fully reproducing the long-distance natural gas transmission process. The LNG receiving terminal simulation platform aligns with national energy security policy orientations, integrating simulation subsystems for LNG carriers, unloading, storage, recondensation, and vaporization. Together with safety production simulation control software and a process numerical simulation platform, it enables highly realistic training for the safe operation of the entire LNG receiving terminal process. Through a multi-level, full-process simulation environment, students systematically enhance their engineering practice and comprehensive decision-making abilities in the field of oil and gas gathering and transportation.

Petrochemical engineering training zone

This training zone is modeled on an actual catalytic cracking unit. By integrating teaching methods such as 3D virtual simulation, scenario-based task construction, and multimedia interaction, it establishes a series of process training platforms covering key equipment, including regenerators, reactor settlers, catalyst hoppers, fractionation towers, strippers, air coolers, and heat exchangers. The platform not only supports students in systematic cognition and high-fidelity simulation operation of the catalytic cracking process but also enables multi-dimensional comprehensive training in equipment structure principles, safety standard operations, fault diagnosis and emergency response, and equipment disassembly, assembly, and maintenance. This forms a teaching resource system that combines virtual and physical elements and integrates theory with practice. At the same time, the platform's flexible component configuration promotes deep integration of teaching and research. It supports students, based on mastering equipment principles and process flows, in conducting research on structural optimization, performance enhancement, and process innovation, thereby achieving the full-chain talent cultivation goal from basic cognition and skill training to scientific research and innovation ability development.

Virtual simulation comprehensive training zone

The Virtual Simulation Comprehensive Training System consists of four mutually supportive teaching modules: HSE Safety Education, Panoramic VR Simulation of Oil and Gas Production, New Energy Comprehensive Training, and Internet of Things (IoT) Comprehensive Training. The HSE Safety Education Module focuses on typical accident types in the oil and gas industry, such as mechanical injury, electric shock, impact by objects, and fire/explosion. Through simulation operations and scenario-based drills, it helps students master key skills including the use of personal protective equipment, risk identification, emergency response, and accident management, thereby strengthening safety risk awareness and standardized operating habits. The Panoramic VR Module for Oil and Gas Production constructs a virtual production site covering the entire chain of drilling, oil production, and gathering/transportation. Students can freely navigate and perform interactive operations from a first-person perspective, intuitively understanding equipment structures, process flows, and safety regulations in a highly realistic working environment. Embedded knowledge-based modules further integrate on-site perception with theoretical learning. The New Energy Comprehensive Training Module is framed around the "source, grid, load, storage, and control" synergistic system. It builds a photovoltaic power generation simulation system, a wind power simulation platform, an adjustable load unit, and an integrated energy monitoring platform, supporting students in conducting comprehensive practice such as system design, operation regulation, and energy efficiency analysis. The IoT Comprehensive Training Module covers multiple units, including simulation processes, instruments, networking and video, automatic control and configuration, fault diagnosis, and tools. It supports stepwise skills training from primary level (instrument wiring, local area network setup) to intermediate level (system debugging, parameter setting) to advanced level (host computer development, control algorithm research), meeting the practical needs of students at different levels and from various disciplinary directions.

INTEGRATED FUNCTIONS AND EDUCATIONAL OUTCOMES

The platform has evolved from a singular teaching environment into a comprehensive educational carrier, forming a multi-level functional system centered on virtual simulation, supported by labor education, and extended through science popularization.

Virtual simulation practical teaching

As the core function, the team has developed a series of simulation projects and curriculum resources Practical teaching serves as the core function of the Oil and Gas Industry Virtual Simulation Practice Teaching Platform. Relying on typical production training equipment covering the entire industrial chain and its supporting virtual simulation software, the teaching team closely aligns platform operations with actual production and professional talent cultivation objectives. Centered on the competency requirements of various professional positions, the team has systematically deconstructed internship and training projects along the industrial chain, resulting in a series of virtual simulation training projects and course resources that deeply match actual production and are highly compatible with the platform's functions.

In terms of teaching methods, adhering to a "student-growth-centered" philosophy, the team has innovatively adopted three forms of practical teaching: desktop-based, immersive, and experiential. Following a four-level progression- "basic professional cognition - virtual simulation experiments - simulation-based internship and training - technological innovation training"—students' practical and innovative abilities are cultivated step by step. Regarding evaluation and assessment, the main thread of "learning-practicing-assessing-evaluating" runs through the entire practical teaching process, with emphasis on process-oriented assessment. A diversified assessment system comprising "system evaluation - intra-group peer evaluation- instructor final evaluation" has been established, forming a closed-loop control system for continuous improvement of practical teaching processes and quality.

Practice has shown that the high-quality virtual simulation practice teaching platform and its accompanying series of virtual simulation projects have significantly enhanced the capacity for practice-based education, yielding a number of highly visible and impactful teaching achievements: (1) The platform has supported programs such as Petroleum Engineering, Resource Exploration Engineering, Chemical Engineering and Technology, and Process Equipment and Control Engineering in successively being designated as national-level "first-class majors" or receiving engineering education accreditation, thereby driving an overall improvement in the teaching quality of core disciplines. (2) It has supported practice-oriented courses such as Petroleum Drilling and Production Machinery and Introduction to Petroleum Industry and Carbon Neutrality in being selected as national or provincial level first-class courses. Practical teaching outcomes have received honors including the First Prize for Higher Education Teaching Achievements of Shaanxi Province in 2023 and the Special Prize for Teaching Achievements of the China Petroleum Education Society in 2024. (3) The platform is deeply integrated into the cultivation of students' engineering practice abilities, serving as a "training ground" for developing their capacity to solve complex engineering problems. Teaching practice shows that after the same cohort of students completes individual training tasks, when they subsequently undertake similar individual tasks and comprehensive practical projects, their completion time is reduced by approximately 15%, the average accuracy rate of team operations, as indicated by system logs, increases by approximately 8%, and their practical ability to solve real-world problems in engineering, machinery, design, and drafting is significantly enhanced. During 2024–2025, the number of first- and second-prize awards won by students in high-level disciplinary competitions—such as the National Petroleum Engineering Design Competition, the Oil and Gas Geology Competition, and the Chemical Engineering Design Competition—increased by approximately 12%, achieving an organic integration of knowledge, abilities, and value cultivation. The enhancement of practical abilities has also been highly recognized by employers. Enterprises such as Changqing Oilfield, Tarim Oilfield, Yanchang Oilfield, and PipeChina have consistently reported that graduates "demonstrate strong practical abilities and adapt quickly to job positions," establishing a solid reputation within the industry.

Professional labor education

The oil and gas industry virtual simulation practical teaching platform, which features cuttingedge industry characteristics and covers the entire industrial chain, can effectively remedy the deficiencies in implementation carriers and professional integration within traditional labor education, thereby providing tangible practical support for professional labor education. Although such virtual simulation practice differs from labor performed under harsh natural conditions on the production frontline, it remains a form of professional practical labor, as exemplified by positions such as the intelligent wellsite control post and the indoor operator post in a chemical plant. Hence, a labor education practice base deeply integrated with the distinctive features of the petroleum and petrochemical industry has emerged. By simulating real industrial scenarios and systematically incorporating job technical specifications and engineering ethics requirements, the base has constructed a series of "productive labor" education projects with "industry-education integration" at their core. These projects cover typical oil and gas production operation scenarios, including drilling well control operations, oil and gas gathering and transportation process regulation, and HSE safety training (see Table 1). They realize the transformation of industry technical standards (e.g., API, SY/T specifications) into teaching evaluation indicators, and the conversion of professional processes into teaching content, thereby embedding professional spirit and career commitment throughout labor education.

Taking the project "Oil and Gas Gathering and Transportation Process Operation and Regulation" as an example, this project is designed against the backdrop of production operations at an oil and gas gathering and transportation station. By assuming the role of a shift operator at the station, students use a SCADA (Supervisory Control and Data Acquisition) system on the simulation training platform to monitor in real time key process parameters—such as pressure, temperature, and flow rate—as well as equipment operating status, and perform dynamic analysis and adjustments to ensure the safe, stable, and efficient operation of the gathering and transportation system.

The project comprises three labor tasks designed around the core responsibilities of a gathering station operator:

(1) Parameter monitoring and recording: Using the DCS (Distributed Control System) interface, students read real-time operating parameters including pipeline pressure, temperature, and flow rate, identify whether the parameters are within normal ranges, and complete operation reports in a standardized manner.

(2) Operational regulation and control: Based on parameter changes, students perform corresponding process adjustments. These include controlling pipeline pressure by adjusting valve openings or pump speeds, controlling temperature by regulating the combustion condition of the heating furnace, and adjusting flow rate via variable frequency drives or valves. In actual operation, pressure, temperature, and flow rate are interrelated; students must learn to consider all parameters comprehensively and perform coordinated regulation.

(3) Inspection, troubleshooting, and recording: Following a prescribed inspection route, students conduct simulated inspections, examining key equipment such as the heating furnace, separators, and the external pumping house one by one. They record operational data including equipment temperature, pressure, and flow rate, promptly address any anomalies, and complete inspection records.

As frontline guardians of the safe operation of the gath-

Table 1: Labor Education Projects with Petroleum and Petrochemical Characteristics

Project Name	Job Description
Drilling Well Control Simulation Emergency Operation	Simulates the positions of driller and assistant driller on a drilling crew, performing standardized well shut-in and kill operations in response to hazards such as kicks and blowouts.
Oil and Gas Gathering and Transportation Process Operation and Regulation	Acts as a shift operator at a gathering and transportation station, monitoring and regulating pipeline pressure, temperature, and flow rate to ensure stable system operation.
Refining and Chemical Unit Start-up and Shutdown Operation	Simulates inside and outside operators, completing a series of operations according to procedures, including unit preheating, oil introduction, circulation, and shutdown purging and isolation.
HSE Risk Identification and Emergency Response	Serves as a on-site safety officer, identifying hazards and assessing risks in virtual scenarios, and organizing initial responses to emergencies such as fires and leaks.
Downhole Tool Operation	Acts as a tool administrator or operator for a workover crew, performing tool selection, inspection, assembly, and simulated downhole deployment.
IoT Equipment Commissioning and Data Inspection	Simulates an intelligent oilfield operation and maintenance role, checking the status of virtual sensors, RTUs, and other equipment, performing fault diagnosis, and conducting data acquisition and analysis.

ering system, operators must remain on duty in the central control room 24 hours a day. This project introduces real occupational scenarios into the labor education classroom, enabling students to experience the work status of frontline workers in a simulated professional environment. Through immersive experience in this role, students genuinely understand the principle that "labor creates value, and labor creates a better life," respect ordinary workers, and firmly embrace the belief that "labor is the most glorious, the most noble, the greatest, and the most beautiful." They come to realize that it is the silent dedication of countless operators that ensures the safe and smooth transport of national energy supplies. Practice has shown that production-oriented labor practice grounded in real production scenarios significantly enhances students' sense of identification with the hardworking and enterprising spirit of the energy industry, as well as their professional mission. It comprehensively improves students' engineering practice ability, safety awareness, teamwork spirit, and innovative literacy, achieving an organic integration of labor value shaping, professional knowledge instruction, and comprehensive ability development.

Extended function: Science popularization education

Leveraging the strong interactivity and intuitive presentation advantages of the Oil and Gas Industry Virtual Simulation Practice Teaching Platform, the university has established a "Petroleum Industry Science Popularization and Teaching Base" open to the public. The base focuses on disseminating energy knowledge and technology, and regularly organizes themed signature activities such as the "Petroleum Industry Science Journey" and "Little Scientist Growth Camp." In the full year of 2025, the base organized a total of 8 research and visiting sessions, held 2 science popularization competitions, conducted 11 sessions of a series of outreach lectures ("into schools, villages, enterprises, and communities"), participated in 6 events related to the National Science and Technology Week and National Science and Technology Day, and hosted 9 other social science popularization visits. Over the year, the base served more than 5,000 members of the public.

Survey data indicate that prior to visiting, approximately 66.2% of the audience had only a "general understanding" of the petroleum industry—knowing, for example, that petroleum is the raw material for gasoline and plastics. About 60% of the audience believed that the petroleum industry is closely related to daily life but lacked knowledge of the principles and processes of exploration, development, and refining. After systematic science popularization education, the level of understanding improved significantly: 77.2% of the audience reported "some improvement" or "significant improvement" in their understanding of petroleum formation and exploration; the proportion of people recognizing that petroleum is an important chemical raw material capable of producing numerous chemical products increased to 73.6%. The construction and operation of this base have effectively addressed the issue of underutilized practical teaching resources, broken the stereotypical view that university social services remain hidden in an "ivory tower," and achieved a deep integration of science popularization education and social service. (Figure 2–3)

While steadily enhancing its capacity for practice-based education, the platform has also achieved significant breakthroughs in qualification building and social influence. The labor education base and science popularization education base, centered on the Oil and Gas Industry Virtual Simulation Platform, have been successively designated as the "Shaanxi Provincial Labor Education Base for Universities, Middle Schools, and Primary Schools," the "Shaanxi Provincial Science Popularization Education Base (2023–2027)," the "Science Popularization Education Base of the Chinese Petroleum Society," and the "Xi'an Science Popularization Education Venue (2025)." Building on these qualifications, the teaching team has further successfully secured a series of science

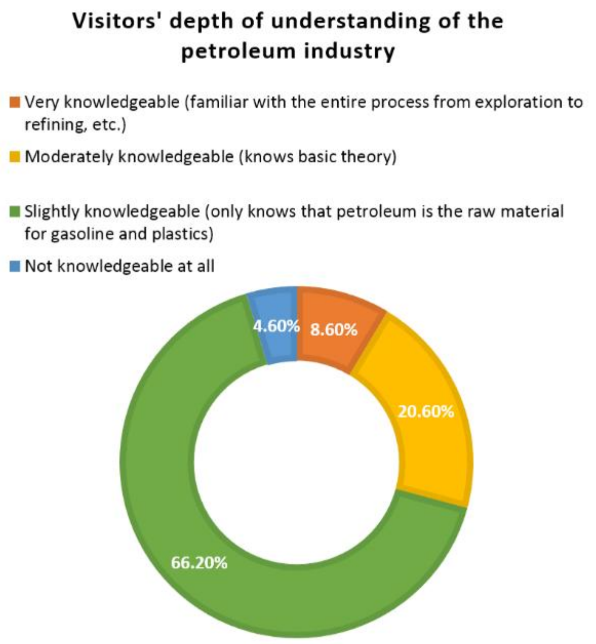

Figure 2. Level of public understanding of the "petroleum industry" before the visit

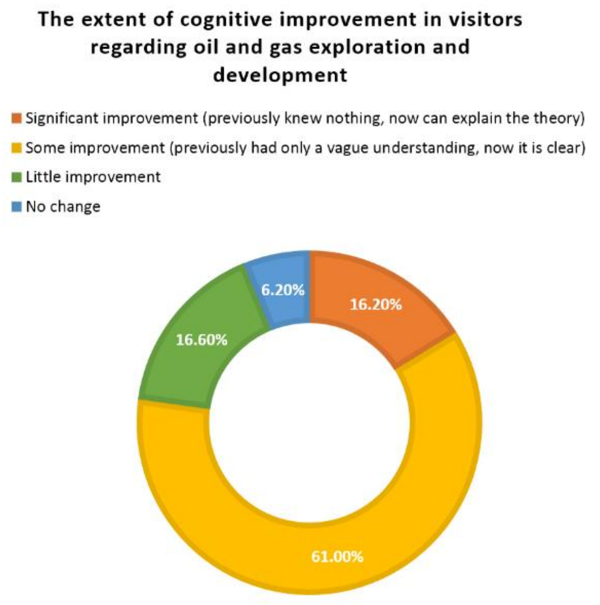

Figure 3. Enhancement of public understanding of "oil and gas exploration and development" after the visit

popularization research projects, including projects in the Science Communication category of the National Natural Science Foundation of China (NSFC), the Resource Integration and Demonstration Project of the China Association for Science and Technology (CAST), and a science popularization special project of the Xi'an Science and Technology Bureau. This has achieved synergistic progress in platform construction and project application, effectively propelling the university's scientific and technological innovation and social service capabilities to a higher level. The achievements in construction and reform have been highly praised by industry experts from the China Petroleum Education Society and the Shaanxi Association for Science and Technology, and have been widely reported by central and local mainstream media such as *Xuexi Qiangguo*, Shaanxi Satellite TV, and CNWEST. They have also attracted attention from industry peers including the Petroleum Industry Training Center of China University of Petroleum (East China), the Museum of Northwest University, the Training Center of Changqing Oilfield, and the Science and Technology Department of Yanchang Oilfield, gradually forming a brand effect with both industry recognition and public influence.

VALUE FOR DISSEMINATION AND PROMOTION

From the perspective of practical teaching reform and platform construction, the achievements of the multifunctional integration development of the Oil and Gas Industry Virtual Simulation Practice Teaching Platform are by no means accidental. Rather, they represent a concentrated reflection of the continuous deepening of education and teaching reform and the active exploration of new engineering education pathways. Against the macro-background of the national push for digital transformation in education and the cultivation of outstanding engineers, the exploration and practice of this platform offer a valuable reference model for engineering universities seeking to deepen the reform of engineering talent cultivation and enhance their social service capabilities.

(1) Deepening the virtual simulation-oriented positioning of practical teaching through platform construction. Unlike traditional training equipment, which suffers from slow updates and high maintenance costs, this platform fully leverages the advantages of technologies such as VR and digital twins to transform the "high-input, high-risk, high-pollution" operating environment of the petroleum industry into "immersive, interactive, zero-risk" training scenarios. This effectively addresses the long-standing problems in production internships for petroleum and petrochemical majors: "inability to access, inability to see, and inability to operate." The *Opinions on Accelerating the Digitalization of Education*, issued by nine departments including the Ministry of Education in 2025, emphasize that higher education and vocational education should develop high-quality digital courses and virtual simulation internship and practice resources covering all disciplines, while increasing the supply of resources such as those for labor education. This construction approach—grounded in real industrial scenarios and supported by virtual simulation—aligns closely with the reform direction advocated by new engineering education, namely "upgrading traditional engineering disciplines through intelligentization."

(2) Achieving a systematic transformation of "technical standards – teaching content – value guidance." The platform translates industry technical standards into teaching evaluation indicators, transforms typical professional processes into teaching content, and embeds professional spirit and career commitment throughout the educational process. This practical model of "bringing standards into the classroom, bringing job posts into the curriculum, and bringing professional spirit into students' minds" effectively bridges the gap between university education and industrial needs, ensuring that teaching content keeps pace with industrial technological development. It resonates with the requirement of outstanding engineer cultivation reform to "break the problem of engineering talent cultivation being disconnected from production practice," providing a highly valuable example for practical teaching reform in engineering universities and for building a new model of industry-education collaborative talent cultivation.

(3) Exploring an open-ended construction pathway of "campus practice – social service – brand building." This platform breaks the traditional limitation of practical teaching resources being confined to campus and serving a single teaching audience. Through science popularization education open to the public, it has enabled the transition of scientific and technological resources from the "ivory tower" to a "high ground for social service." The continuous development of the science popularization education brand and the extensive coverage by mainstream media have not only enhanced the university's industry recognition and public influence but have also provided a useful reference for similar institutions seeking to solve the problem of "underutilized practical teaching resources."

(4) Constructing a sustainable development ecosystem of "project traction – industry recognition – collaborative linkage." The successful acquisition of a number of high-level science popularization projects—including projects in the Science Communication category of the NSFC *(National Natural Science Foundation of China)*, the Resource Integration and Demonstration Project of CAST *(China Association for Science and Technology)*, and a science popularization special project of the Xi'an Science and Technology Bureau—marks the platform's transition from spontaneous exploration to a research-driven, systematic development stage. With strong support from high-quality projects, the platform's achievements have received high praise from industry experts at the Shaanxi Association for Science and Technology and the China Petroleum Education Society, professionally validating the correctness of the reform direction and the significance of the outcomes. This industry recognition has further stimulated exchanges, collaboration, and resource sharing with benchmark industry organizations, effectively expanding the reach of practical teaching reform. Multilateral collaboration has built a virtuous cycle for sustainable development. Thus, a replicable and scalable paradigm for practice base construction has preliminarily taken shape, providing solid empirical support for engineering universities to "build well, use effectively, and gain recognition for" their practice platforms.

In summary, the exploration and practice of the Oil and Gas Industry Virtual Simulation Practice Teaching Platform demonstrate that reform and innovation oriented toward multi-functional integration constitute a feasible pathway for achieving connotative development of practice teaching platforms in engineering universities. It is foreseeable that with the continued deep integration of cutting-edge technologies such as artificial intelligence and digital twins into practical teaching, this new paradigm of practice-based education—using virtual simulation platforms as a carrier, industry-education integration as a pathway, and social service as an extension—will provide increasingly robust and powerful support for the cultivation of high-quality engineering talent.

CONCLUSION

(1) The functional positioning of the Oil and Gas Industry Virtual Simulation Practice Teaching Platform has evolved from a single-function to a multi-functional model, systematically responding to the contemporary transformation of higher education's talent cultivation demands. The platform transcends the traditional boundaries of teaching functions, establishing an integrated system of "practical teaching as the core, professional labor education as the support, and science popularization service as the extension." This system systematically incorporates real industrial scenarios and technical specifications into specialized labor courses, while simultaneously offering science popularization services to the public outside of regular teaching hours. It effectively addresses structural challenges such as the disconnect between labor education and professional practice, the underutilization of university practical resources, and the weakness of social service functions, thereby achieving the integration of educational resources and the synergistic expansion of functions.

(2) The construction and reform pathway of this platform demonstrates strong potential for dissemination and replicability. The series of reform initiatives not only significantly improves the quality of engineering practice-based education but also simultaneously enhances the university's social reputation and resource utilization

efficiency. The successful experience provides a validated and transferable reference paradigm for the construction and development of practice teaching platforms in engineering universities.

DECLARATION

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Author Contributions

Dong Zhao was responsible for the construction of the virtual simulation practice teaching platform for the oil and gas industry and the drafting of the manuscript. Baohong Shi contributed to the proposal and implementation of the multifunctional development concept for the practice teaching platform. Juntao Zhang was in charge of the reform of virtual simulation practice teaching methods. Lei Zhang conducted the reform and implementation of labor education. Yihong Song carried out science popularization and was responsible for the translation and revision of the manuscript. Ziheng Chen and Qingben Li were respectively responsible for the application and management of the science popularization education base and labor education base. Guowang Gao organized the manuscript materials. Wei Qu drew the figures and illustrations. Guoxiang Chen and Hongyan Shen were specifically involved in the development of practical training courses and science popularization activities, and they also provided project funding support.

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Ethical approval

Not applicable.

Informed consent

Not applicable.

Conflict of interest

The author has no conflicts of interest to declare.

Use of large language models, AI and machine learning tools

None declared.

Data availability statement

No additional data.

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