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Exploration of Digital and Intelligent Empowerment Pathways for Curriculum Construction in Oil and Gas Storage and Transportation Majors — Taking "Oil and Gas Pipeline Transportation" as an Example

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Project Title: Exploration of Digital and Intelligent Empowerment Pathways for Curriculum Ideological and Political Education in Oil and Gas Storage and Transportation Majors: Taking "Oil and Gas Pipeline Transportation" as an Example

Abstract: The deep integration of digital technology with the oil and gas industry has led to a continuous increase in demand for compound digital-intelligent talents, while traditional teaching models struggle to adapt to industry transformation. Taking the course "Oil and Gas Pipeline Transportation" as a case study, this paper analyzes pain points such as the disconnect between teaching and field practice, limited practical scenarios, and monotonous teaching models. It constructs a digital-intelligence-enabled development pathway: restructuring course content, building a digital twin virtual simulation platform, innovating blended online and offline teaching, and fostering a dual-skilled teaching team. By integrating big data, digital twins, and virtual simulation technologies into all stages of the course, and establishing mechanisms for school-enterprise co-construction and resource sharing, teacher training, and hardware support, the approach ensures a precise alignment between talent cultivation and industry demands, providing a replicable reference for the digital transformation of the oil and gas storage and transportation specialty.

Keywords: Digital intelligence empowerment; oil and gas storage and transportation; curriculum development; oil and gas pipeline transportation; talent cultivation

Introduction

China's oil and gas pipelines have entered the "smart pipeline network" stage, with technologies such as digital twins, intelligent regulation, and AI inspection being widely implemented. The industry's requirements for graduates' capabilities have expanded from traditional process design to digital-intelligent operation, maintenance, and big data analysis. Taking this course as a starting point, this paper explores the deep integration of digital-intelligent technologies with professional courses, reconstructs the teaching system, and provides a theoretical basis and practical plan for adapting the oil and gas storage and transportation specialty to digital transformation and improving the quality of talent cultivation.

1. Analysis of the Current Status and Pain Points of Traditional Teaching in the "Oil and Gas Pipeline Transportation" Course

1.1 Disconnection between Teaching Content and the Intelligent Development of the Industry

The knowledge system of the traditional course "Oil and Gas Pipeline Transportation" primarily revolves around classical theories such as process calculations for oil pipelines, hydraulic characteristics of gas pipelines, and pipeline operation condition adjustments. It covers very few of the emerging digital intelligence technologies widely applied in the industry today, such as intelligent pipeline network control, digital twin pipeline modeling, and fault diagnosis based on pipeline big data. Related content is only briefly mentioned as supplementary knowledge, without forming a systematic teaching module. The update cycle of textbooks generally lags behind the pace of technological iteration in the industry. Most case studies discussed in class are based on conventional pipeline engineering scenarios from a decade ago, leaving students with a vague understanding of technologies already common in current actual projects, such as intelligent split-flow distribution and AI-based leak detection. This results in a significant gap between the knowledge students acquire at school and the actual demands of their future positions.

1.2 There Are Significant Limitations in Practical Teaching Scenarios and Resources

Long-distance oil and gas pipelines represent a special engineering scenario with high risks and costs. The physical site does not allow large-scale hands-on training for students. Most practical components of traditional courses rely on small indoor experimental benches, which can only simulate the local hydraulic characteristics of short-distance pipelines and cannot replicate the full operating conditions of thousands-of-kilometers-long transmission pipelines. As a result, it is difficult for students to intuitively understand abstract concepts such as transient flow in pipelines, water hammer propagation, and coordinated control of the entire pipeline system. They also lack access to real-world engineering systems like SCADA control systems and intelligent operation and maintenance platforms. The depth and breadth of practical training are severely limited, making it challenging to cultivate students' ability to solve complex engineering problems [1].

1.3 The Single Teaching Mode Fails to Stimulate Students' Innovative Thinking

Most traditional courses adopt a single teaching model of "lecture-based instruction plus after-class assignments," where the classroom is primarily dominated by one-way knowledge transmission from the teacher. Students remain in a passive receiving state, and interaction between teachers and students is largely limited to question-and-answer sessions on knowledge points. This makes it difficult to guide students in actively exploring the innovative applications of digital and intelligent technologies in pipeline engineering. The course assessment method mainly relies on closed-book written exams, focusing heavily on students' memorization of formula calculations and theoretical concepts. The evaluation weight for students' engineering practice skills and their ability to apply digital and intelligent tools is extremely low, which fails to stimulate innovative thinking and cannot comprehensively measure students' overall professional competence.

2. Objectives and Framework Design for the Digital and Intelligent Empowerment of the "Oil and Gas Pipeline Transportation" Course

2.1 Course Construction Goal Positioning

The overall goal of integrating digital and intelligent technologies into the course "Oil and Gas Pipeline Transportation" is to cultivate composite pipeline engineering talents with data literacy and intelligent decision-making capabilities. To achieve this goal, a three-dimensional capability cultivation model is constructed. In the knowledge dimension, students are required to master classical hydraulics, thermodynamics, and the fundamental principles of pipeline operation, while understanding the application logic and applicable boundaries of data-driven methods in scenarios such as pipeline condition analysis, leak detection, and operation optimization. In the capability dimension, students are expected to use programming tools (Python or MATLAB) to process, analyze, and visualize pipeline operation data, build simplified data-driven models to solve specific engineering problems, and conduct pipeline operation scheme comparison and optimization based on simulation platforms. In the literacy dimension, students are trained to develop an engineering mindset of supporting decisions with data and a critical perspective on the output of intelligent systems. These three dimensions progress step by step, forming a closed-loop capability system of "solid principles, proficient tools, and scientific thinking."

2.2 Overall Framework of Course Development

Based on the aforementioned objectives, an overall curriculum framework of "one main line, two supporting pillars, and four progressive stages" is constructed. The main line is the cultivation of "data-driven pipeline transportation system analysis capabilities," which runs through the entire course. All teaching content, practical activities, and evaluation tasks are centered around this main line. The two supporting pillars are the "teaching resource platform" and the "virtual-real combination experimental platform," working in tandem: the former hosts digital teaching resources (micro-lessons, case libraries, datasets, and literature banks), while the latter supports simulation training and data analysis practices. The four progressive stages divide the learning process into "theoretical foundation → virtual simulation → data analysis training → comprehensive innovative practice," with clear goals and close connections at each stage, guiding students from knowledge acquisition to capacity building [2]. The framework design follows the principles of "industry-education integration, data connectivity, virtual-real combination, and continuous iteration," ensuring that the construction plan is both forward-looking and feasible.

3. Specific Implementation Paths for Digital Intelligence-Enabled Course Development

3.1 Reconstructing a Modular Teaching Content System that Integrates Data and Intelligence

Break away from the traditional linear chapter-based content structure by restructuring the course into three major content modules: “Fundamental Theory Module,” “Digital Intelligence Expansion Module,” and “Engineering Innovation Module.” The Fundamental Theory Module retains core classic content such as crude oil pipeline transportation, natural gas pipeline transportation, and batch pipeline transportation, solidifying students’ professional theoretical foundation. The Digital Intelligence Expansion Module adds cutting-edge content such as digital twin pipeline modeling, big data analysis of pipeline operations, intelligent leak detection and localization, and operation of smart pipeline network SCADA systems, supplemented by the development of the latest industry case base for smart pipeline network projects, transforming real digital intelligence projects from the National Pipeline Network Group into teaching resources. The Engineering Innovation Module sets up open-ended topics, guiding students to independently explore innovative applications such as drone inspection and intelligent pipeline corrosion prevention using tools like Python data analysis and AI image recognition. This approach enables students to establish a comprehensive digital intelligence professional knowledge system while still in school.

3.2 Building a Full-Scene Virtual Simulation Practice Platform Driven by Digital Twins

A domestic intelligent pipeline technology company has jointly developed a digital twin virtual simulation platform for "Oil and Gas Pipeline Transportation" with the United Nations. Based on a real thousands-kilometer-long domestic oil and gas pipeline, the platform reproduces the pipeline's geographic route, station equipment, and operation control system at a 1:1 scale. Students can complete the entire process operation training on the platform, from pipeline commissioning and debugging, normal condition regulation, water hammer accident emergency response, to full life cycle operation and maintenance. The platform's big data module can generate realtime multi-condition pipeline operation data, which students can access to conduct characteristic analysis and develop intelligent control algorithms to optimize operation plans, breaking through the limitations of physical experimental setups and immersing them in real engineering field operation scenarios.

3.3 Building an Online-Merge-Offline Digital-Intelligent Hybrid Teaching Model

Leveraging online course platforms, a digital resource pool is established for courses, incorporating resources such as knowledge-point micro-videos, 3D station models, and engineering operation demonstration animations. Students can autonomously preview foundational knowledge points before class, while the platform automatically records their learning data and accurately identifies their weak areas. In the classroom, the focus shifts from one-way lectures to project-based teaching, where students engage in group discussions centered on real pipeline engineering problems and collaboratively design solutions using digital tools [3]. After class, personalized tutoring is carried out through the digital teaching platform, delivering customized supplementary learning resources tailored to individual students' progress, thereby facilitating the transition from a "teacher-centered" to a "learner-centered" teaching model and significantly enhancing classroom teaching efficiency.

3.4 Build a School-Enterprise Collaborative Dual-Teacher Teaching Team

Establish a two-way exchange mechanism between university faculty and enterprise digital intelligence technology experts. Regularly select in-school teachers to participate in on-site training at smart pipeline operation and maintenance sites, getting involved in the digital and intelligent project construction of real-world engineering projects to enhance their own digital engineering practical capabilities. Meanwhile, hire technical experts from enterprises as part-time lecturers to enter the classroom and share their actual work experience, explaining the application cases of digital intelligence technology in oil and gas pipeline sites, enabling students to directly understand the latest technological developments at the industry frontline. Organize regular training sessions for the teaching team on digital and intelligent teaching methods, helping them master teaching skills such as virtual simulation platform operation and big data analysis tool application, thereby building a dual-qualified teaching team that is proficient in both classical storage and transportation theory and cutting-edge digital intelligence technology.

4. Key Guarantee Measures for the Construction of Digital and Intelligent Courses

4.1 Establishment of a School-Enterprise Resource Co-Construction and Sharing Mechanism

The sustained advancement of digital and intelligent curriculum development relies on stable, high-quality resource supply, and the core of resource supply capability lies in breaking down barriers between universities and industry enterprises. On one hand, universities should proactively sign long-term strategic cooperation agreements with leading domestic oil and gas pipeline enterprises, clarifying the rights and responsibilities of both parties in areas such as curriculum development, case sharing, data anonymization for use, and joint construction of training platforms. This will transform the smart pipeline projects already implemented by enterprises into teachable educational resources. For example, real SCADA operational data from an in-service pipeline of the National Pipeline Network Group can be anonymized for student data analysis training, while the engineering experience of enterprise digital twin pipeline modeling can be converted into teaching cases. On the other hand, enterprises should view university curriculum development as a preliminary step in their own talent reservoir, actively participating in curriculum content review and teaching plan optimization to ensure dynamic alignment between teaching content and job competency requirements. Both parties should establish a regular resource update mechanism, conducting a benchmark of teaching content against industry technology each semester, integrating the latest digital and intelligent technological achievements into curriculum modules promptly, to prevent teaching content from falling behind again [4].

4.2 Tiered Training and Incentives for Faculty Digital Intelligence Competence

Teachers are the core executors of curriculum reform implementation, and their digital-intelligent teaching abilities directly determine the quality of course development. To address the prevalent capability gaps among current teaching staff—such as "understanding storage and transportation but not data, and grasping theory but not platforms"—a tiered training strategy should be implemented. For new young teachers, they are required to complete specialized skill training in Python data analysis and digital twin platform operation within three years of employment and obtain qualification certificates, with digital-intelligent teaching ability incorporated into the assessment criteria for their trial lectures. For mid-career key teachers, opportunities should be provided through school-enterprise cooperation channels to work in enterprise intelligent operation and maintenance departments, participate in actual engineering digital-intelligent projects, and achieve capability transformation in real business scenarios. For senior teachers, the focus should be on enhancing their ability to apply digital-intelligent teaching resources, ensuring they can proficiently use virtual simulation platforms and online teaching tools. Meanwhile, universities should improve the supporting incentive mechanisms for curriculum reform by incorporating the workload of developing digital-intelligent teaching resources and designing virtual simulation experiment projects into the teaching performance evaluation system, providing special course hour subsidies and achievement recognition. This creates a positive incentive loop that effectively motivates teachers to actively participate in curriculum reform.

4.3 Digital-Intelligent Teaching Hardware Environment and Operational Assurance

Digital-intelligent teaching places higher demands on hardware environments compared to traditional classrooms, requiring the establishment of a stable and reliable technical support system. First, dedicated digital-intelligent teaching laboratories or smart classrooms should be built, equipped with high-performance graphics workstations, large-screen display systems, and multi-position interactive devices to support the high-fidelity operation of virtual simulation platforms and group discussion-based teaching. Second, a course-specific cloud computing resource pool should be established to ensure computing performance and response speed when students simultaneously access digital twin platforms or call upon big data analysis tools during peak hours, preventing technical lags from affecting the teaching experience. Third, a 7×24 technical operations and maintenance team should be set up to handle version updates, data backups, and rapid fault resolution for virtual simulation platforms, ensuring that the continuity of teaching activities is not disrupted by technical failures. Fourth, a long-term storage and security management system for teaching data should be implemented, categorizing and archiving modeling results and analysis reports generated during student training. This not only serves as original records of student learning trajectories for teaching research but also provides data support for subsequent course optimization, forming a closed-loop iterative mechanism of "teaching—data—optimization."

Conclusion

Digital and intelligent technologies have brought new opportunities for the reform of oil and gas storage and transportation courses. Taking "Oil and Gas Pipeline Transportation" as an example, this paper systematically addresses the key issues of "how to construct and implement" digital and intelligent courses by reconstructing modular teaching content, building digital twin virtual simulation platforms, innovating hybrid teaching models, fostering school-enterprise collaborative dual-teacher teams, and establishing supporting mechanisms for resource sharing, tiered teacher training, and hardware operation assurance. This model breaks the limitations of traditional teaching, which are constrained by restricted scenarios and outdated content, effectively bridging campus teaching and engineering practice. As digital technologies continue to evolve, the digital and intelligent construction of oil and gas storage and transportation courses will deepen, cultivating more high-quality composite talents for smart oil and gas pipeline construction.

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