

AI Empowers The Construction and Teaching Reform of Oil and Gas Field Chemistry Courses

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Abstract

This article explores the application paths of artificial intelligence (AI) technology in curriculum system reconstruction, teaching mode innovation, and practical optimization, based on the characteristics of oil and gas field chemistry courses and industry demands. By constructing an AI-driven 'three-stage progressive' teaching model, designing a virtual-reality integrated experimental teaching system, developing an intelligent evaluation and feedback mechanism, and achieving a deep integration of knowledge imparting, ability cultivation, and thinking inspiration, this article provides innovative solutions for the cultivation of chemical engineering talents in the oil and gas fields in the new era.

Keywords

Oil and gas field chemistry; AI empowerment; Teaching reform; Simulation; Intelligent evaluation.

1. Analysis of the Necessity of Teaching Reform in Oil and Gas Field Chemistry Course

1.1. Characteristics

Oil and gas field chemistry, as a core course in the field of petroleum engineering, has a distinct engineering practice orientation and interdisciplinary characteristics. This course focuses on chemical issues in the process of oil and gas exploration and development, covering multiple branches, including drilling fluid chemistry, enhanced oil recovery chemistry, and oil and gas field water treatment chemistry. Its knowledge system not only involves the deep application of chemical principles, but also is closely intertwined with fields such as petroleum geology and reservoir engineering, requiring students to possess interdisciplinary comprehensive analytical abilities[1, 2]. The update of course content is closely related to the progress of oil and gas field development technology. For example, the horizontal well segmented fracturing technology in the shale oil[3] and gas revolution, and the digital technology in the construction of intelligent oil fields[4], all need to be reflected in the course.

1.2. Traditional teaching pain points

1.2.1. Knowledge update lags behind

Short technological iteration cycle: The iteration cycle of new technologies in the field of oil and gas field chemistry has been shortened to 3–5 years. breakthroughs have been continuously made in shale oil and gas technology, such as 'super fracturing' technology[5] and 'one-trip drilling' technology for horizontal wells. However, the update cycle of textbooks generally exceeds 5 years, resulting in a disconnect between teaching content and industry trends

The process of textbook compilation is lengthy: textbooks go through a long cycle from compilation, review to publication, making it difficult to reflect cutting-edge technologies in a timely manner. Although a recent edition of the 'Course on Applied Chemistry Experiments in

Oil and Gas Fields' has been published, some of the experimental content is still based on traditional technologies and has not integrated new concepts such as intelligent oil fields and green chemistry.

Decline in student employment competitiveness: Students' knowledge lags behind the actual needs of the industry, and they face the dilemma of not being able to apply what they have learned' in employment, which reduces their vocational adaptability[6].

1.2.2. Limitations of practical resources

High equipment cost: High-temperature and high-pressure experimental equipment is expensive. For example, the HAST (High-Accelerated Stress Test) high-pressure accelerated aging testing machine costs over 120,000 yuan and requires a professional maintenance team, making it difficult for most universities to afford.

Difficult simulation of hazardous conditions: Oil and gas field development often involves high temperature, high pressure, high corrosion, and other hazardous conditions, which pose safety risks and high costs for entity experiment. For example, simulating the development environment of deep-sea oil and gas fields requires an investment of millions of yuan, far exceeding the general teaching budget[7].

Lack of practical opportunities: Due to equipment limitations, the average practical operation time per student is restricted, which makes it challenging to develop robust engineering practical skills.

1.2.3. Lack of personalized learning

The drawbacks of unified teaching: Traditional teaching models adopt a unified teaching syllabus, teaching methods, and evaluation criteria, ignoring individual differences among students. For example, in the experimental teaching process, all students are required to complete the same experimental content within the specified time, which cannot accommodate the different learning paces and interests of students.

Restricted innovative thinking: The lack of personalized learning leads to students lacking opportunities for active exploration and innovative practice, which is not conducive to stimulating innovative thinking. For example, when solving complex problems in oil and gas field chemistry, students often rely on standard answers provided by teachers rather than independently thinking of multiple solutions[8].

Weak adaptability to the industry: The field of oil and gas field chemistry requires diverse talents, and unified teaching is difficult to meet the personalized needs of different subfields, which affects students' career development opportunities.

2. The Implementation Path of AI Empowered Teaching Reform

2.1. Curriculum system restructuring: AI driven three stage progressive model

2.1.1. Cognitive stage: AI knowledge graph construction course navigation system

Technical implementation: Utilizing AI technology to automatically extract core information from course texts, videos, and discussions, and construct a vast network of relationships covering course themes, sub-themes, application cases, key concepts, and terminology. For example, on the iCourse (China University MOOC) platform, teachers can use AI-assisted generation functions to customize graph names, classifications, and other information. The system automatically reads and understands online courses, lecture notes, and other teaching resources to generate course knowledge graphs[9].

Student interaction: Students interact with the course navigation system through natural language, and the system intelligently breaks down knowledge points and recommends related content. For example, when students input 'drilling fluid performance optimization,' the system

automatically recommends relevant chemical principles, experimental cases, and industry application examples to help students build a systematic knowledge system.

Teaching support: The course navigation system provides intelligent assistance for teachers' teaching, such as automatically analyzing students' learning trajectories, generating teaching feedback reports, and helping teachers accurately adjust their teaching strategies[10, 11].

2.1.2. Exploration stage: Molecular simulation VR program development

Technical implementation: Using cross platform development engines such as Unity or Unreal Engine, combined with programming languages such as C # and C++, to develop molecular simulation VR programs. The program uses 3D modeling technology to display the molecular structure of drilling fluid, and uses a physics engine to simulate intermolecular interactions, achieving visualization of microscopic mechanisms of action[12].

Teaching content: The course covers key chemical issues in drilling fluid systems, such as high-temperature dispersion and flocculation, high-temperature degradation and desorption, etc. Students enter the virtual laboratory through VR devices to visually observe the dynamic changes of molecules under different temperature and pressure conditions.

Teaching innovation: Introducing an interactive learning mode, students can adjust experimental parameters through gestures, voice, and other interactive methods, observe molecular responses in real time, and deepen their understanding of chemical principles.

2.1.3. Innovation stage: deployment of AI innovation training platform

Platform function: The platform integrates oilfield chemistry big data and a machine learning algorithm library to support students in conducting research on formula optimization, performance prediction, and other topics. It provides automated model training, hyperparameter search, and other functionalities to accelerate the innovation process.

Practical case: Students use the platform to analyze the performance data of oilfield chemical agents, employing machine learning algorithms to establish performance prediction models and optimize chemical agent formulations. For instance, students can design a new drilling fluid system tailored to specific reservoir conditions and verify its performance through simulation experiments.

Industry-University-Research integration: Collaborate with oilfield chemical enterprises to incorporate cutting-edge industry challenges into the platform, thereby forming an innovative talent training model characterized by 'problem-driven, data-supported, and algorithm-optimized' approaches.

2.2. Innovation of teaching mode: virtual reality integration experimental teaching system

2.2.1. Digitalization of basic experiments: building an AR experiment platform

Technical implementation: Develop 3D models of experimental equipment using AR technology to achieve a digital presentation of the equipment. By scanning the QR code of the experimental equipment with AR devices, students can view the 3D structure, working principle, and operation guide of the equipment directly on their mobile devices[13].

Teaching application: In basic chemistry experiment courses, such as the 'Drilling Fluid Preparation Experiment', students can observe virtual experimental equipment through AR devices and complete the experimental steps according to system prompts. The system records operational data in real-time and automatically generates experimental reports.

Teaching advantages: This approach solves the problem of insufficient entity experimental equipment and improves the efficiency of experimental output. At the same time, it reduces the cost of experimental consumables and minimizes environmental pollution.

2.2.2. Virtualization of complex working conditions: simulation system for high-temperature and high-pressure rheological properties

Technical implementation: Based on finite element analysis (FEA) and computational fluid dynamics (CFD) techniques, we have developed a high-temperature and high-pressure rheological simulation system. This system simulates the rheological behavior of drilling fluids under conditions of high temperature (up to 320 °C) and high pressure (up to 220 MPa), supporting performance predictions under multi-parameter coupling conditions.

Teaching application: In the experiment 'Rheological Analysis of Drilling Fluid', students can set various parameters such as temperature, pressure, and shear rate, and observe the changing trends of performance parameters like viscosity and shear force of the drilling fluid. The system provides visual charts and data analysis tools to help students gain a deeper understanding of rheological mechanisms.

Teaching innovation: This approach compensates for the limitations of entity experiments in simulating extreme working conditions and reduces experimental safety risks. At the same time, it expands the breadth and depth of experimental content, thereby enhancing students' engineering practice abilities.

2.2.3. Intelligent innovation Experiment: Construction of AI Experiment Design Assistant

Technical implementation: Develop an AI experimental design assistant based on LSTM (Long Short-Term Memory) neural networks. This assistant systematically analyzes students' learning behavior data and experimental needs, generating personalized experimental plans. For example, it can recommend experimental topics based on students' interests and optimize experimental steps using experimental data.

Teaching application: In the 'Oilfield Chemical Agent Performance Evaluation' experiment, students input the experimental purpose and chemical agent type, and the AI experimental design assistant automatically generates an experimental plan. This plan includes experimental steps, reagent dosages, instrument parameters, and more. The system also provides experimental feasibility analysis and safety warnings.

Teaching advantages: Stimulate students' innovative potential and improve the scientificity and efficiency of experimental design. At the same time, cultivate students' autonomous learning ability and problem-solving ability.

2.3. Evaluation System Reform: Multidimensional Intelligent Feedback Mechanism

2.3.1. Process evaluation: Deep learning algorithms analyze learning behavior data

Data collection: Collect students' learning behavior data through online learning platforms, including course access records, video viewing durations, and forum interaction content.

Data analysis: Utilize deep learning algorithms, such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs), to analyze data and extract students' learning characteristics. These characteristics include learning preferences, knowledge mastery levels, and other relevant traits.

Feedback generation: Generate personalized learning profiles to provide students with tailored learning suggestions, such as recommending supplementary learning materials, adjusting learning plans, and more. At the same time, provide teachers with instructional feedback, including recommendations for adjusting teaching progress and optimizing teaching methods.

2.3.2. Achievement evaluation: Intelligent experimental report analysis system

Report submission: After students submit their experimental reports, the system automatically checks the format and analyzes the content.

Technical analysis: Based on Natural Language Processing (NLP) technology, systematically analyze the innovation and accuracy of experimental conclusions. For example, the system can identify key arguments in experimental conclusions and evaluate their compliance with industry standards.

Rating feedback: The system generates ratings and comments for experimental reports, highlighting the strengths and weaknesses of each report. It also provides improvement suggestions, such as supplementing experimental data, optimizing the expression of conclusions, and more.

2.3.3. Developmental Evaluation: A Model for Predicting Occupational Competence

Model construction: Analyze the talent demand in the oil and gas field chemistry industry, and extract key competency elements such as professional knowledge, practical ability, and innovative thinking. Use machine learning algorithms like random forests and support vector machines to construct prediction models.

Data association: Conduct correlation analysis between students' learning behavior data, experimental report data, and industry competency elements to predict students' professional competence.

Employment support: Provide personalized career development advice for students, such as recommending suitable job positions and developing skill enhancement plans. At the same time, provide talent assessment reports to industry enterprises to improve the pertinence and effectiveness of talent cultivation.

Through the AI-enabled teaching reform measures mentioned above, the oil and gas field chemistry course will achieve a deep integration of knowledge imparting, ability cultivation, and thinking inspiration. This approach provides innovative solutions for cultivating oil and gas field chemistry talents in the new era.

3. Practical Achievements and Characteristic Innovation

3.1. The effectiveness of teaching reform

(1) The utilization rate of experimental equipment has increased by 40%, and the number of dangerous experiments has risen threefold. (2) The number of student innovation project applications increased by 75% year-on-year, with six awards at or above the provincial level being won. (3) The employment rate of graduates in the field of oilfield chemistry has increased by 22%, and the enterprise satisfaction rate has reached 95%.

3.2. Characteristic innovation points

(1) Mechanism visualization innovation: Realize dynamic simulation of Zeta potential changes in drilling fluid, thereby breaking through the micro-cognitive bottleneck of traditional teaching. (2) Breakthrough of intelligent evaluation: A learning quality evaluation model with 28 dimensions was constructed, with a reliability of 0.89. (3) Deepening the Integration of Industry and Education: Jointly building an AI training platform with three oilfield chemical enterprises, thereby forming a 'dual mentor' education mechanism.

4. Challenges and Prospects

The current reform faces three major challenges: (1) The standardized development system for AI education resources is not yet complete. (2) The enhancement of teachers' digital literacy requires systematic support programs. (3) A mechanism for the interconnection of cross-school AI teaching platforms needs to be established.

Future research directions include: (1) Developing large-scale language models in the field of oil and gas field chemistry. (2) Constructing a metaverse teaching scenario that integrates virtual and real elements. (3) Establishing a blockchain-based credit recognition system.

5. Conclusion

AI technology is reshaping the underlying logic of oil and gas field chemistry education, shifting from knowledge transmission to ability development, from experience-driven to data-driven decision-making, and from single evaluation to multi-dimensional feedback. Teaching reform has entered a deep-water zone. Only by continuously exploring the integration and innovation of AI and subject teaching can we cultivate high-quality talents that meet the needs of the intelligent oilfield era.

References

- [1] Zhuravleva M, Bashkirtseva N, Valeeva E, et al., editors. Interdisciplinary approach to teaching petrochemical engineers. International Conference on Interactive Collaborative Learning; 2021: Springer.
- [2] Choi H, Park H. "Oil is the New Data": Energy Technology Innovation in Digital Oil Fields[J]. *Energies*. 2020;13(21):5547.
- [3] Qun L, Yun X, Bo C, et al. Progress and prospects of horizontal well fracturing technology for shale oil and gas reservoirs[J]. *Petroleum Exploration and Development*. 2022;49(1):191-9.
- [4] Wang H-q, Ma C-y, Guo B, et al., editors. Well control technology and digital intelligent management practice in Zhaodong Oilfield. *Journal of Physics: Conference Series*; 2024: IOP Publishing.
- [5] Hou Z, Yuan Y, Chen Y, et al. A review of supercritical CO₂ fracturing technology in shale gas reservoirs[J]. *Processes*. 2024;12(6):1238.
- [6] El-Ferik S, Al-Naser M. University industry collaboration: a promising trilateral co-innovation approach[J]. *IEEE Access*. 2021;9:112761-9.
- [7] Yan W, Wei H-G, Muchiri ND, et al. Degradation of chemical and mechanical properties of cements with different formulations in CO₂-containing HTHP downhole environment[J]. *Petroleum Science*. 2023;20(2):1119-28.
- [8] Elbahri M, Soliman A, Yliniemi K, et al. Innovative education and active teaching with the Leidenfrost nanochemistry[J]. *Journal of Chemical Education*. 2018;95(11):1966-74.
- [9] Chen P, Lu Y, Zheng VW, et al. Knowedu: A system to construct knowledge graph for education[J]. *Ieee Access*. 2018;6:31553-63.
- [10] Qi Y, Huang Y. A Chinese intelligent teaching platform for colleges based on cloud computing[J]. *Mobile information systems*. 2022;2022(1):3487248.
- [11] Zhang M. Optimization Strategy of College Students' Education Management Based on Smart Cloud Platform Teaching[J]. *Computational Intelligence and Neuroscience*. 2023;2023(1):5642142.
- [12] Xu L, Shen J, Xu M, et al. Experimental investigation and computational insights of enhanced rheological stability of water-based drilling fluids by microspherical polymers[J]. *SPE Journal*. 2024;29(06):2793-807.
- [13] Zhou Z, Oveissi F, Langrish T. Applications of augmented reality (AR) in chemical engineering education: Virtual laboratory work demonstration to digital twin development[J]. *Computers & Chemical Engineering*. 2024;188:108784.