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Research on Restructuring Undergraduate Teaching Curriculum System for Interdisciplinary Talents Oriented to Dual Carbon Goals and Green Mines - A Case Study of Double First-Class Energy Disciplines

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Abstract: Aiming at the special training demands of interdisciplinary talents for Dual Carbon Goals and Green Mines, this paper explores optimization and reconstruction strategies of undergraduate teaching curriculum systems. The existing curriculum system for Oil and Gas Field Development Engineering features excessive overlapping content and wasted teaching class hours. This study puts forward curriculum integration strategies. It first sorts out core practical problems and industrial scenarios related to Dual Carbon Goals and Green Mines under Outcome-Based Education orientation, analyzes overlapping characteristics among different courses, and reconstructs the whole curriculum system. This paper provides specific curriculum restructuring cases. The reconstructed curricula attach importance to integrated application of theories and technologies, delivering new ideas and practical experience in Energy Disciplines.

Keywords: Interdisciplinary Talents; Outcome-Based Education; Undergraduate Teaching; Double First-Class Disciplines; Curriculum System

1. Introduction

1.1 Training Demands for Emerging Engineering Interdisciplinary Talents

Petroleum engineering belongs to an industry with high carbon emission and intensive carbon utilization. Students trained in this discipline undertake core responsibilities in the delivery of Dual Carbon strategic targets[1-2]. The Dual Carbon Goals raise new requirements for talent cultivation, calling for interdisciplinary professionals equipped with carbon emission management capacity, energy-saving and emission-reduction research capabilities, as well as practical engineering operation skills[3-4]. The Green Mine concept highlights ecological constraints and sustainable development paths for mineral resource exploitation. The construction of Emerging Engineering Education requires breaking the traditional boundaries of single disciplines [5-6].

The integration of the three dimensions reshapes core training objectives of undergraduate education. As the fundamental carrier of talent cultivation, the organizational framework of curriculum systems directly shapes students' knowledge architecture. Fundamental transformation of training goals cannot be fulfilled through partial curriculum revisions; systematic integration guided by training outcomes becomes an inevitable choice.

1.2 Development Status of Branch Courses After Discipline Subdivision

Taking Oil and Gas Field Development Engineering as an example, its curriculum system has evolved from a single series centered on Reservoir Engineering into multiple independent courses, including Reservoir Physics, Seepage Mechanics, Modern Production Decline Analysis, and Principles of Enhanced Oil Recovery. Repetitive content between courses increases alongside continuous subdivision. Such course groups divided by technical workflows operate with independent teaching schedules and separate assessment standards, leading to increasingly prominent overlapping content issues in daily teaching practice.

2. Necessity and Urgency of Curriculum System Restructuring

2.1 High Overlap Degree Across Different Courses

Content crossover widely exists within the current curriculum framework. After multiple rounds of teaching iteration, every course retains a large proportion of introductory basic content to maintain its own logical integrity and systematicness. Such repetition is not simple redundant text. Each teaching module regards its introductory theoretical foundation as irreplaceable and refuses to cut relevant sections to guarantee internal teaching continuity.

2.2 Consistent Core Teaching Objectives Among Courses

The Outcome-Based Education framework provides systematic solutions to the content repetition dilemma. Reviewing existing courses under this theoretical framework reveals that each course elaborates one single facet of reservoir engineering issues, yet all modules point toward identical ultimate training targets. Reservoir Physics illustrates physicochemical properties of reservoir rocks and formation fluids. Reservoir Engineering covers material balance calculation, production decline rules and water cut rising laws. Principles of Enhanced Oil Recovery introduces water flooding, chemical flooding, gas flooding and thermal recovery technologies. Though offered as separate subjects, these three courses revolve around the identical core task: designing development plans based on reservoir physical characteristics. Students repeatedly learn identical basic logical frameworks through parallel independent courses, failing to build complete problem-solving capabilities.

3. Methods and Ideas for Curriculum System Restructuring

3.1 Summarization of Core Practical Problems and Industrial Scenarios Oriented to Dual Carbon Goals and Green Mines

This research first categorizes core engineering challenges emerging in petroleum industry sites. Training outcomes derived from these practical problems serve as guidance to deduce required competency indicators, further supporting the redesign of curriculum frameworks. Engineering challenges can be classified into three major categories based on industrial logic:

1) Forward problems relying on static geological data: generating digital geological models and predicting dynamic reservoir development responses;

2) Inverse problems relying on production data: inverting reservoir physical parameters and evaluating development performance with field production records;

3) Project design: formulating rational development strategies under given reservoir conditions and preset production targets.

3.2 Curriculum System Restructuring Guided by Training Outcomes

Courses serving identical core engineering targets are integrated according to the three problem categories above:

For forward modeling tasks: Petroleum Reservoir Geology, Reservoir Characterization and Geological Modeling, and Principles of Petroleum Reservoir Numerical Simulation collectively target predicting development dynamics from static geological data.

For inverse analysis tasks: Seepage Mechanics, Well Test Analysis, and Modern Production Decline Analysis focus on recognizing reservoir characteristics via inverse deduction from production data.

For project design tasks: Reservoir Physics, Reservoir Engineering, and Principles of Enhanced Oil Recovery support the whole workflow of field development planning.

Curriculum integration does not equal simple content splicing. Knowledge chains are reorganized following practical problem logic. Repeated introductory theoretical segments are explained only once after integration. Saved class hours are allocated to strengthen comprehensive technical application and industrial case practice sessions.

4. Case Analysis

4.1 Core Practical Industrial Scenarios of Oil and Gas Field Development Engineering Oriented to Training Outcomes

Scenario 1: Evaluating Water Flooding Performance and CO_2 Enhanced Oil Recovery Potential in Low-Permeability Oilfields

Students need to master physicochemical properties of reservoir rocks and fluids (Reservoir Physics), grasp material balance calculation and dynamic monitoring methods (Reservoir Engineering), and assess applicable conditions plus technical economy of CO_2 flooding technologies (Enhanced Oil Recovery). Under traditional teaching arrangements, these three knowledge modules are delivered in separate courses across three semesters, forcing students to integrate scattered knowledge independently during practical work. Restructured curricula help students form complete capabilities of formulating full-set development plans targeting this industrial scenario.

Scenario 2: Constructing Digital Twin Systems Integrating Geological Modeling, Numerical Simulation and Dynamic Prediction for Mature Oilfields

Students extract static geological information through core sample observation and well logging interpretation (Petroleum Reservoir Geology), convert raw geological data into three-dimensional digital geological models (Reservoir Geological Modeling), and input established models for numerical calculation and long-term development prediction (Reservoir Numerical Simulation). Traditional teaching artificially separates geological characterization and numerical simulation into disconnected segments.

4.2 Demonstration and Discussion

(1) Integrated curriculum targeting inverse mathematical modeling of seepage flow

Reservoir Physics, Seepage Mechanics, Well Test Analysis and Modern Production Decline Analysis are merged into Theory of Seepage Mechanics and Dynamic Analysis Technology. Reservoir Physics covers physicochemical features of reservoir media and fundamental multi-phase seepage rules. Seepage Mechanics centers on establishing mathematical forward models describing underground fluid flow. Interpretation charts in Well Test Analysis originate directly from analytical solutions of seepage governing equations. Modern Production Decline Analysis extends seepage theories to long-term reservoir-scale dynamic evaluation. All original courses address similar inverse engineering problems. After integration, the unified theoretical framework of forward modeling is constructed once, with all subsequent inverse deduction methodologies developed within this consistent system.

(2) Integrated curriculum targeting development scheme design in oil and gas exploitation

Reservoir Engineering and Principles of Enhanced Oil Recovery are combined into Principles and Technologies of Reservoir Engineering. The integrated curriculum forms the theoretical foundation of full-cycle oilfield development planning. Reservoir Engineering takes Reservoir Physics and Seepage Mechanics as basic theories, introducing design standards and analytical methods for oilfield exploitation. Principles of Enhanced Oil Recovery elaborates core exploitation technologies including water flooding, chemical flooding, gas flooding and thermal recovery. The integrated module takes systematic analytical approaches of reservoir engineering as its core logic, ultimately focusing on practical enhanced oil recovery theories and field technologies.

(3) Integrated curriculum targeting forward modeling for integrated digital oilfield platforms

Petroleum Reservoir Geology, Reservoir Characterization and Geological Modeling, and Principles of Petroleum Reservoir Numerical Simulation are integrated into Digital Characterization and Integrated Simulation of Petroleum Reservoirs. Petroleum Reservoir Geology provides fundamental static reservoir description technologies, covering stratigraphic correlation, structural interpretation, reservoir quality evaluation and fluid distribution analysis. The three original courses follow a progressive industrial workflow: geological characterization → model construction → numerical simulation. The integrated curriculum starts with static reservoir characterization methods from petroleum geology, converting qualitative geological understanding into three-dimensional digital geological models. Emerging Engineering elements such as intelligent oilfield technologies and multi-source data fusion are embedded into the unified teaching framework after restructuring.

5. Conclusion

Curricula of petroleum engineering disciplines feature consistent training objectives yet scattered separated teaching modules, resulting in wasted class hours, fragmented knowledge logic and insufficient cultivation of students' comprehensive problem-solving abilities. Guided by Outcome-Based Education theories, this study integrates multiple scattered courses and optimizes the overall curriculum framework. Reservoir Physics, Seepage Mechanics, Well Test Analysis and Modern Production Decline Analysis are integrated into Theory of Seepage Mechanics and Dynamic Analysis Technology, enabling all inverse deduction methods to be delivered under a unified theoretical framework. Reservoir Engineering and Principles of Enhanced Oil Recovery are merged into

Principles and Technologies of Reservoir Engineering, connecting the full thinking chain from reservoir physical property recognition to complete development scheme design within a single course. Petroleum Reservoir Geology, Reservoir Characterization and Geological Modeling, and Principles of Petroleum Reservoir Numerical Simulation are combined as Digital Characterization and Integrated Simulation of Petroleum Reservoirs.

The three integrated curriculum modules respectively correspond to three core competency dimensions: static forward modeling, dynamic inverse analysis and integrated development scheme design. The optimized curriculum system under Outcome-Based Education reduces repetitive teaching hours and consolidates coherent knowledge logic. Within limited undergraduate learning cycles, students can develop comprehensive capabilities to tackle complex practical engineering challenges.

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