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From "Mechanical Embedding" to "Organic Integration": Epistemological Logic and Teaching Path of Ideological and Political Education in Petroleum Engineering Courses

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Abstract **Original Research Article**

Against the dual backdrop of global energy transition and emerging engineering construction, talent cultivation in petroleum engineering faces a critical shift from a single technical paradigm to a socio-technical paradigm. Future petroleum engineers must master cutting-edge technologies for deep-earth exploration and oil-gas development, while fostering a strong sense of national energy security, ecological ethical responsibility, and professional resilience. Nevertheless, ideological and political construction in science and engineering courses generally falls into the practical dilemma of "mechanical embedding", where value elements are treated as additional content separate from professional knowledge. This creates a disconnect between ideological education and professional teaching, further widening the divide between instrumental rationality and value rationality. Drawing on socio-technical system philosophy and situated learning theory, this study critiques the limitations of traditional superimposed approaches. Taking Southwest Petroleum University as a case, it constructs a theoretical framework for the organic integration of ideological and political education in petroleum engineering curricula. This research argues that industry culture represented by the Iron Man Spirit should be redefined as engineers' professional ontology rather than mere political propaganda. The essence of integration lies in shifting from forced external grafting to implicit internal infusion, embedding ethical considerations such as energy security and environmental friendliness as endogenous factors in engineering decision-making. This paper further analyzes practical approaches including the "salt-in-soup" curriculum gene mapping, ethics-constrained project-based learning (PBL), and the dual-mentor system. It provides a replicable model for high-risk, strategically significant engineering disciplines to deeply integrate value guidance with knowledge instruction.

Keywords: Engineering Ethics, Curriculum Ideological and Political Education, Petroleum Engineering, Organic Integration, Socio-Technical System, Professional Ontology.

1. Introduction

Max Weber accurately identified the inherent tension between instrumental rationality and value rationality, a conflict manifested sharply in modern engineering education. Engineering education has long prioritized maximizing technical efficiency, teaching students "how to act optimally" yet neglecting value-oriented inquiries of "why we act" and "what consequences our actions bring". For petroleum engineering—a distinctive discipline—this separation of technology and value generates

structural risks. Oil and gas engineering is deeply intertwined with national energy strategies and complex ecosystems, marked by high operational risks and strong strategic importance. In extreme deep-earth and deep-sea environments, drilling engineers' technical decisions, such as wellbore trajectory design or fracturing fluid formulation, determine oil and gas output while directly impacting national energy security, groundwater protection, and public safety. Petroleum engineering is therefore not a value-neutral technical activity, but a quintessential complex socio-technical process.

Though Chinese universities nationwide advance curriculum ideological and political construction, science and engineering teaching suffers from path dependence on "mechanical embedding". When teaching core courses such as rock mechanics and reservoir engineering, many instructors mechanically insert historical narratives or political slogans before quickly returning to pure technical mathematical derivations and model calculations. This oil-water separated teaching model epistemically splits professional knowledge and value concepts. Students perceive ideological elements as redundant add-ons to engineering techniques, failing to apply ethical reasoning autonomously when tackling complex engineering problems. Moving beyond empirical induction, this study explores the theoretical logic to resolve this dilemma from epistemological and pedagogical dimensions. Taking the disciplinary context of Southwest Petroleum University, it constructs a theoretical model of paradigm shift from embedding to integration and elaborates its concrete implementation pathways.

2. Theoretical Framework: From Binary Opposition to Systematic Integration

2.1 Epistemological Restructuring: Socio-Technical Systems Beyond Value Neutrality

Influenced by logical positivism, traditional engineering education adheres to a strict fact-value dichotomy. Within this paradigm, petroleum engineering is reduced to objective computations of fluid mechanics and thermodynamics, framing technology as neutral tools detached from values. Contemporary philosophy of technology, however, posits that engineering is inherently a socio-technical system. Every technical parameter set in the oil and gas sector carries social and ethical implications. For instance, economic calculations for shale gas development must incorporate implicit environmental remediation costs; risk assessments for deep-sea drilling should account for geopolitical variables. Organic integration advocated by curriculum ideological and political education does not impose political will onto science, but restores the intrinsic completeness of engineering knowledge. From this perspective, patriotism for energy supply security and ecological civilization concepts for green development cease to be external moral restraints, and instead become endogenous variables and boundary conditions for optimal engineering design solutions.

2.2 Pedagogical Foundation: Situated Learning and Professional Identity Construction

This study's pedagogical foundation rests on situated learning theory, which contends that abstract values and ethical norms cannot be effectively transmitted through decontextualized preaching, but acquired via legitimate peripheral participation within communities of practice. In teaching practices at Southwest Petroleum University, the Petroleum Spirit is not merely a textbook definition, but tacit knowledge formed through simulating deep-earth high-pressure environments in laboratories and resolving real technical challenges at field training bases. Students demonstrating perseverance, rigorous scholarship, and teamwork while solving complex engineering problems internalize abstract values into their professional ontology. This learning model transforms "knowledge about values" into "practice as values", enabling students to construct professional identities through the socialization of technical expertise.

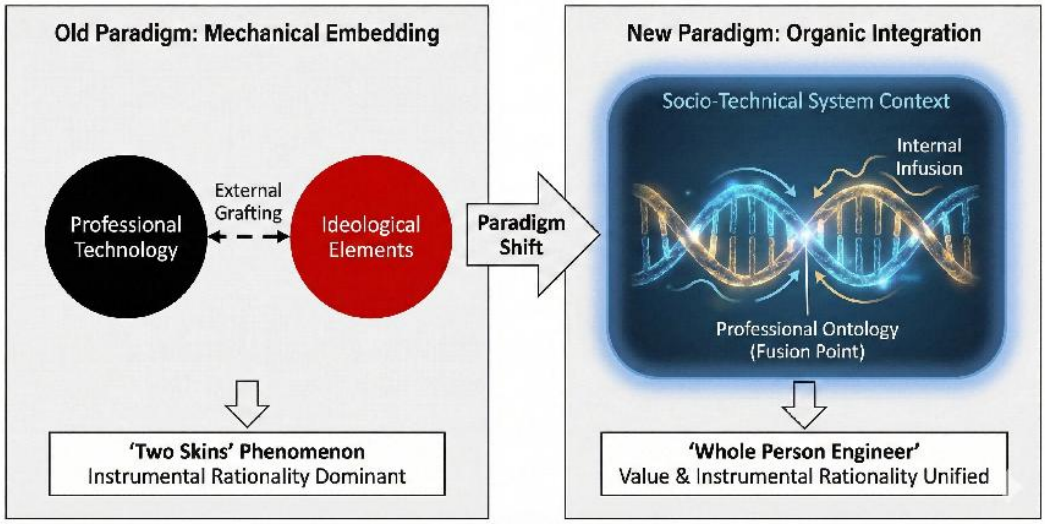

Figure 1 Theoretical Model of Paradigm Shift from Mechanical Embedding to Organic Integration

3. Research Methodology

3.1 Research Design: Exploratory Single-Case Study

This study adopts an exploratory single-case research design. Case studies are well-suited to address the core research question of how to construct theoretical models within complex real-world contexts. Given that organic integration of ideological and political education in science and engineering involves intricate dynamic processes spanning cognitive psychology, instructional design, and organizational culture, mature interpretive frameworks remain absent in academia. Pure quantitative data cannot uncover underlying mechanisms. In-depth analysis of a single representative sample enables extraction of micro-operational mechanisms from complex educational phenomena, facilitating logical abstraction from empirical observations to theoretical models.

3.2 Case Selection: Representativeness of Southwest Petroleum University

Southwest Petroleum University is selected as the sole case due to its extreme representativeness and heuristic value. As a national Double First-Class university and China's second petroleum undergraduate institution founded after the founding of the People's Republic of China, it boasts distinctive industry characteristics and red cultural heritage. Petroleum engineering combines high technical thresholds with strong political and ecological sensitivity, creating more acute conflicts between instrumental and value rationality than general engineering disciplines. It serves as an ideal laboratory for examining socio-technical integration challenges. Furthermore, the school's unique Iron Man Spirit provides abundant cultural foundations for researching the transformation of grand values into engineers' professional ontology, granting unparalleled analytical depth to case analysis.

3.3 Data Sources and Analytical Strategy

A triangulation strategy of multi-source data is adopted to guarantee research reliability and validity. First, textual analysis systematically reviews the university's 2020–2025 undergraduate talent cultivation programs for petroleum and natural gas engineering, syllabi for five core professional courses, and institutional guiding documents for curriculum ideological and political construction, tracking evolving expressions of non-technical competencies in training objectives. Second, instructional review dissects teaching plans, PBL task sheets, and student final design samples for core courses including Drilling Engineering, Oil & Gas

Storage and Transportation Engineering, and Reservoir Engineering, tracing presentation forms of ideological elements across full teaching cycles. Finally, thematic analysis codes all collected materials to extract core categories across three dimensions: instructional objective restructuring, content integration touchpoints, and evaluation system reform, validating and revising the proposed theoretical hypothesis of transition from embedding to integration.

4. Critique of Current Practice: Epistemological Dilemmas of Mechanical Embedding

Current teaching practices exhibit a red-black binary divide: red symbolizes ideological and political education, black represents petroleum engineering technology. Lacking deep logical connections, red cultural genes remain detached from technical systems, failing to construct integrated knowledge maps. For example, when teaching enhanced oil recovery technologies, instructors who merely repeat grand slogans such as "securing domestic oil supply" without explaining how refined water injection technologies reduce resource waste to advance sustainable development render value education hollow and disconnected.

Moreover, students' widespread technical worship exacerbates this dilemma. Within instrumentalist cognitive frameworks, students equate mathematically optimal solutions with absolute truth, overlooking ethical trade-offs embedded in engineering decisions. When confronted with ethical dilemmas—such as cutting safety procedures to meet deadlines or lowering environmental standards to reduce costs—traditional embedded ideological education fails to reshape students' deep cognitive structures, risking ethical misconduct in their future professional careers.

5. Logic of Integration: Restructuring Disciplinary Genes and Value Reorientation

The core of organic integration lies in redefining the positioning of industry values within professional education. The Daqing Spirit and Iron Man Spirit forged through arduous oil and gas exploration and development work should not be reduced to mere moral qualities, but framed as core professional competencies for petroleum engineers. Maintaining rational judgment amid harsh field environments, identifying geological patterns from massive tedious datasets, and sustaining psychological resilience throughout long-term engineering operations are all prerequisites for safe and successful project delivery.

Against the national Dual Carbon Goals, petroleum engineering faces transformative challenges and opportunities. Curriculum ideological and political education must respond to this era-defining agenda, guiding students to develop dialectical energy perspectives: balancing immediate national energy security and efficient conventional oil-gas supply with long-term green transition via carbon capture, utilization and storage (CCUS), geothermal exploitation, and other emerging technologies. This macro-temporal and dialectical mindset cannot be delivered through technical instruction alone, requiring value guidance to align technical logic with national strategic priorities.

6. Practical Paths: Empirical Exploration at Southwest Petroleum University

Based on the above theoretical framework, Southwest Petroleum University has developed three concrete integration pathways in teaching practice, enabling effective translation of theory into practice.

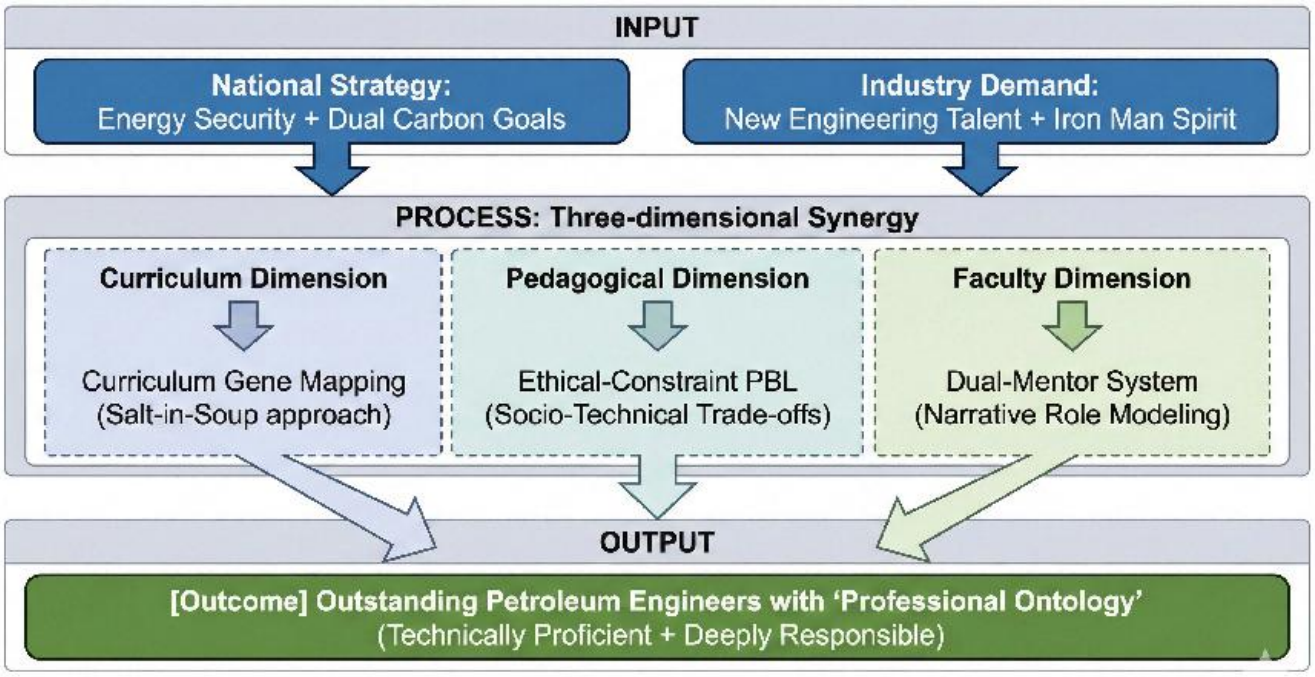

Figure 2 Implementation Pathway of Value Integration

6.1 Curriculum Restructuring: The Salt-in-Soup Gene Mapping Strategy

Abandoning rigid external grafting, the university develops curriculum ideological gene mapping to excavate intrinsic ethical touchpoints within specialized courses. Take Oil & Gas Storage and Transportation Engineering as an example: the chapter on long-distance pipeline hydraulics expands beyond pressure drop calculations and pump station optimization to introduce the macro concept of "energy lifelines". In-depth analysis of technical hurdles faced by the West-East Gas Transmission Project crossing the Yangtze River and Tianshan Mountains illustrates how every decimal point in hydraulic calculations directly impacts urban heating livelihoods and social stability downstream. For well control units in Drilling Engineering, instructors conduct full reviews of the 12·23 catastrophic well blowout accident, requiring students to recalculate neglected formation pressure data and simulate catastrophic consequences of regulatory violations. This transforms ethical requirements of integrity into non-negotiable technical bottom lines rather than empty moral preaching, enabling natural permeation of values as salt dissolves into soup.

6.2 Pedagogical Innovation: Ethics-Constrained Project-Based Learning

The university reforms curriculum design and assessment frameworks by introducing mandatory non-technical constraint indicators that require students to conduct value trade-offs within technical proposals. In the green oilfield development PBL project for Reservoir Development Design, students design development schemes for a shale gas block in the Sichuan Basin. Assessment criteria undergo structural adjustment: economic return accounts for only 60% of total scores, while the remaining 40% evaluates environmental impact assessments and community engagement plans. When technically optimal drilling trajectories conflict with local water source protection zones, students must reconcile maximum output targets with minimal ecological damage. This simulation of real-world socio-technical trade-offs internalizes ecological

civilization principles into every technical decision, cultivating students' capacity for responsible engineering judgment.

6.3 Faculty Collaboration: Narrative Role Modeling and the Dual-Mentor System

To bridge academic theory and industrial practice, the university implements a dual-mentor system pairing academic supervisors with industry supervisors. Senior engineers from leading enterprises including China National Petroleum Corporation and Sinopec deliver field expertise while serving as living industry historians in classrooms. Veteran engineers with firsthand experience of the Tarim Oil Campaign recount real stories of overcoming core technological bottlenecks and enduring months of isolation in uninhabited wilderness. Such narrative role modeling fosters stronger professional identity than abstract indoctrination, validating the professional ontology framework by demonstrating the inseparable unity of patriotism and technical excellence in top-tier engineering practice.

Table 1 Comparative Analysis of Traditional Embedded Mode and Organic Integration Mode

Dimension	Traditional Mechanical Embedding Mode	Organic Integration Mode
Epistemological Foundation	Fact-value dichotomy (Positivism)	Socio-technical system holism
Teaching Objective	Maximize technical efficiency	Synthesized optima of technology, ethics and social impact
Presentation of Ideological Content	Independent, external historical/political preaching	Implicit, endogenous professional ethics and accountability
Core Teaching Methodology	Lecture-based learning	Situated learning and PBL
Student Role	Passive knowledge recipients	Responsible engineering decision-makers
Assessment Criteria	Standardized technical answers	Open-ended schemes incorporating ethical trade-offs

7. Conclusions

This study demonstrates that successful ideological and political education in petroleum engineering hinges on a paradigm shift from superimposed mechanical embedding to infused organic integration. By restoring the socio-technical essence of engineering disciplines, the Petroleum Spirit is reconstructed as engineers' professional ontology and operationalized through situated pedagogy. Theoretically, this paper challenges positivist engineering education assumptions, proving that high-risk engineering disciplines carry unique ethical genes activated through targeted instructional design. Practically, the Southwest Petroleum University model verifies that educational efficacy emerges only when ethical

considerations become endogenous variables in technical decision-making. Ultimately, engineering education aims not merely to train technicians capable of deeper drilling, but to cultivate whole-person engineers who understand where to drill, why to drill, and when to refrain from drilling for human welfare. The transition toward organic integration represents an inevitable return to the humanistic mission of technical education.

References

[1]. Zhang, J., & Zhang, S. (2025). A multimodal data-driven framework and system for evaluating the ideological and political education of courses under the Chinese new engineering science. In *Proceedings of the 2025 7th International Conference on Education Technology, Management and Humanities Science* (pp. 502-509). ACM.

[2]. Smith, N. M., Smith, J. M., Battalora, L. A., & Teschner, B. A. (2017). Social responsibility and petroleum engineering education: Lessons from field-based education. In *SPE Health, Safety, Security, Environment, & Social Responsibility Conference-North America*. Society of Petroleum Engineers.

[3]. McGowan, V. C., & Bell, P. (2020). Engineering education as the development of critical sociotechnical literacy. *Science & Education*, 29(6), 1329-1351.

[4]. Dannels, D. P. (2000). Learning to be professional: Technical classroom discourse, practice, and professional identity construction. *Journal of Business and Technical Communication*, 14(1), 5-37.

[5]. McClelland, C. J., Smith, J. M., & Smith, N. M. (2016). Bringing corporate social responsibility into the petroleum engineering classroom. In *2016 ASEE Annual Conference & Exposition Proceedings*. American Society for Engineering Education.

[6]. Ravesteijn, W., De Graaff, E., & Kroesen, O. (2005). Engineering the future: The social necessity of communicative engineers. *European Journal of Engineering Education*, 30(3), 365-377.