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Curriculum Ideology and Interdisciplinary Integration of Energy Geology for Mining Engineering

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Abstract: Against the backdrop of energy transition and the dual-carbon goals, Energy Geology serves as a core course for mining postgraduates, playing a key role in cultivating high-caliber mining talents. This course faces some major problems: lagging updates to teaching content, insufficient connection between ideological construction and professional instruction, and a low degree of interdisciplinary integration. Taking the teaching reform of mining postgraduates at Chongqing University as an example, this paper explores practical ways to combine value education with interdisciplinary teaching. The reform reconstructs the teaching framework and establishes a trinity curriculum system covering conventional energy, unconventional energy, and non-fossil energy. Combining the deeds of outstanding energy scientists and high-quality ideological elements in the global energy sector, a themed ideological education resource library has been established. Collective lesson preparation and multidisciplinary teacher collaboration are adopted to strengthen interdisciplinary integration. Diversified teaching modes, including flipped classroom and extracurricular practices, are also applied to enrich the training process. Practice shows that the reform has improved teaching effectiveness. It has enhanced professional identity and innovation awareness of postgraduates, providing practical references for the curriculum design of mining postgraduates.

Keywords: Energy Geology; Interdisciplinary Integration; Mining Engineering.

1. Introduction

In the context of global climate change challenges and the strategic goals of peaking carbon dioxide emissions and achieving carbon neutrality, China's energy structure is undergoing a profound transformation, accelerating the transition from a fossil energy-dominated system toward diversification, low-carbon, and clean development [1,2]. Changes in the national energy pattern place higher demands on the knowledge system, comprehensive skills, and professional quality [3]. Future talents need solid traditional geological foundations, up-to-date new energy expertise, strong interdisciplinary thinking, practical engineering skills, patriotic sentiment, and awareness of national energy security [4].

Energy Geology is a core postgraduate course for mining majors. It clarifies formation rules, distribution patterns, and exploration technologies for energy resources [5]. The course links basic geology with practical energy exploration and development, offering essential theoretical support for postgraduate research. High-quality course construction directly improves overall mining discipline development and high-level talent training. Meanwhile, national energy security and low-carbon transition require outstanding energy talents with firm beliefs, professional skills, and global visions [6].

However, the current Energy Geology course has obvious shortcomings. Its content falls behind industrial updates, with shallow integration of ideological education, insufficient cross-disciplinary connections, and monotonous teaching methods [7]. These issues cannot match modern interdisciplinary talent training requirements. Relying on the disciplinary strengths of Chongqing University, the geology teaching team has completed systematic reform of this course. This study summarizes reform strategies, practical measures, and application results from four aspects: optimized curriculum content, enriched ideological resource, interdisciplinary cooperation mechanism, and diversified teaching methods. It hopes to offer useful experience for similar geological courses.

2. Current Situation and Problem Analysis

2.1 Current Teaching Situation

Energy Geology builds its knowledge system around traditional fossil energy. Petroleum, natural gas, and coal are the main teaching contents, focusing on their organic genesis theory, "source-reservoir-cap-trap-migration-preservation" factors, basin analysis and resource evaluation methods [7,8]. It integrates sedimentology, organic geochemistry, structural geology, and other theories, forming a relatively systematic knowledge framework. Meanwhile, it focuses on cultivating the ability of students to solve practical energy exploration problems using geological theories and emphasizes practical skills such as field geological observation, comprehensive experimental analysis, and geophysical interpretation.

Specifically, the traditional teaching content has four modules. The first is basic energy geology theories, including energy classification, the relationship between energy and geological processes, and global energy distribution. The second is core petroleum geology content, covering six key elements: source rock, reservoir, cap rock, trap, hydrocarbon migration and accumulation, and preservation. The third is coal geology, involving coal formation and coalification, coal petrology and geochemistry, coal-bearing basin analysis, and joint coal and coalbed methane exploration. The fourth is energy resource evaluation methods, resource estimation, favorable zone optimization, and exploration deployment principles.

2.2 Existing Problems Analysis

With the accelerated energy transition and advancement of higher education reform, the limitations of the original teaching system have become increasingly prominent.

(1) The curriculum content is updated slowly. Emerging energy fields such as shale oil and gas, natural gas hydrates, geothermal energy, hydrogen energy, and nuclear energy are only briefly introduced without systematic elaboration, leading to a disconnection with industrial community.

(2) The curriculum fails to fully align with the carbon peaking and carbon neutrality strategy. It lacks sufficient coverage on geological theories and applications for low-carbon key technologies such as carbon capture, utilization, and storage (CCUS), making it difficult to meet the talent demands of low-carbon development.

(3) The integration of curriculum ideological education remains superficial. Value guidance concerning energy security and industrial mission is mostly presented in conceptual statements, rather than being deeply integrated with professional knowledge.

(4) Disciplinary barriers are obvious. The relatively closed curriculum system lacks interdisciplinary integration with geophysics, geochemistry, and rock mechanics. This hinders students from developing systematic thinking and cannot satisfy the training requirements for interdisciplinary high-end energy talents.

3. Teaching Content Restructuring Based on Disciplinary Advantages

To address the above problems, the geology teaching team of Chongqing University relies on the disciplinary accumulation and regional advantages in mining engineering, and carries out systematic restructuring of the teaching content of Energy Geology. A new trinity teaching system of conventional energy, unconventional energy, and non-fossil energy has been established, forming a hierarchical and dynamic curriculum content system.

3.1 Conventional Energy Geology: Consolidating the Foundation

Conventional petroleum and gas geology is the fundamental module of the course. In the teaching reform, the team adheres to consolidating basic theories and practical skills for students. The core framework of source-reservoir-cap-trap-migration-preservation is retained, with three major aspects further strengthened.

(1) Latest research advances are integrated, such as progress in fine-grained sedimentology and deep hydrocarbon accumulation theories.

(2) Case teaching is enhanced. Typical petroliferous basins, such as the Sichuan Basin and Ordos Basin, are adopted as cases to guide students to analyze reservoir forming conditions, summarize hydrocarbon accumulation rules, and evaluate exploration potential.

(3) Practical orientation is highlighted. Based on the geological conditions of Chongqing areas, field geological investigation routes are redesigned. Students can observe petroleum geological features, collect and test samples, and conduct comprehensive interpretation in specific geological settings.

3.2 Unconventional Energy Geology: Broadening Academic Vision

Unconventional energy is an important support during the energy transition and a key expansion direction of curriculum reform. The teaching team constructs an integrated teaching module covering shale oil and gas, tight gas, coalbed methane, and natural gas hydrate.

The shale oil and gas module focus on shale reservoir types, pore structure, hydrocarbon enrichment, and sweet spot evaluation. Taking continental shale oil and gas in eastern Chongqing as examples, it analyzes hydrocarbon accumulation characteristics and exploration practices in the Sichuan Basin.

The tight gas module takes Jurassic continental tight sandstone gas reservoirs in the Sichuan Basin as the research object, covering tight reservoir genesis and geological characterization, source-reservoir assemblage, hydrocarbon migration-accumulation mechanisms, and reservoir-forming models.

The coalbed methane module involves coal adsorption-desorption, multi-field coupling of coalbed methane accumulation, and geological controls on production dynamics of wells. Case teaching is combined with exploration and development practices of the Longtan Formation in the Sichuan Basin and Permian strata in the Ordos Basin.

The natural gas hydrate module introduces its crystal structure, phase equilibrium conditions, accumulation system, and geophysical identifications, and overview of global field trial production progress and development prospects.

3.3 Non-fossil Energy Geology: Forward-looking Layout

Facing the long-term goal of carbon neutrality, the curriculum reform prospectively incorporates non-fossil energy geology, including hot dry rock geothermal resources, uranium deposits, and natural hydrogen energy.

The hot dry rock module covers types and genetic mechanisms of geothermal systems, lithospheric thermal structure, and terrestrial heat flow features. It introduces the engineering principles of Enhanced Geothermal System (EGS), resource evaluation methods, and development potential. Combined with typical zones such as the southeast coastal areas, and Songliao Basin, it discusses the distribution of geothermal resources and the application prospect of clean geothermal utilization [9].

The uranium resource module focuses on major deposit types such as sandstone-type and unconformity-type uranium deposits. It illustrates the geochemical behavior of uranium, metallogenic models, as well as exploration and evaluation technologies, clarifying the strategic position of uranium resources in the nuclear energy industrial chain [10].

The hydrogen energy geology module mainly introduces genetic types, migration and enrichment mechanisms, and geochemical exploration methods. It summarizes global research progress in natural hydrogen exploration and inspires students to reflect on the disciplinary connotation and development prospect of hydrogen geology [11].

4. Systematic Construction of Curriculum Ideological Education Resource Library

Curriculum ideological education is a core starting point for the teaching reform and practice of postgraduate Energy Geology courses [6].The geology teaching team of Chongqing University deeply integrates ideological education with professional teaching. Drawing on the touching deeds of outstanding scientists in this university and ideological elements in the global energy field, the team has systematically built a themed curriculum ideological education resource library. It realizes the unity of value shaping, ability cultivation, and knowledge imparting.

The resource library mainly covers eight dimensions.

(1) Strengthening awareness of national energy security. Combined with the current high external dependence on energy and geopolitical layout, it guides students to recognize the strategic significance of energy independence and controllability, and fosters their sense of hardship and responsibility.

(2) Promoting the spirit of scientists. Taking great scientists, who once studied or worked at Chongqing University, such as Siguang Li, Jiqing Huang, Zhongjian Qiu, and Xuefu Xian, it highlights their dedication to the country, dedication to frontline work, and courage to scale scientific heights, making the spirit of scientist’s tangible and learnable.

(3) Cultivating the craftsmanship spirit. Through professional links such as reservoir evaluation and logging interpretation, it emphasizes professional ethics of rigorous precision and

authentic data, and cultivates the pursuit of excellence in students.

(4) Integrating ecological civilization concepts. In teaching of energy development, it incorporates mine ecological restoration, CCUS, and other technologies, guiding students to coordinate development and ecological protection and establish green development awareness.

(5) Inspiring confidence in scientific and technological innovation. By reviewing technological breakthroughs from the terrestrial oil generation theory to shale gas and natural gas hydrate exploration, it highlights the importance of independent core technologies and strengthens the mission of serving the country.

(6) Tempering the spirit of hard struggle. Combined with pioneering exploration deeds in western China, it helps students understand the strategic position of energy resources in western China, and inspires their aspiration to take root in frontline posts and serve Great Western Development Strategy.

(7) Broadening the vision of a community with a shared future for mankind. Based on the Belt and Road cooperation and global energy governance, it enables students to understand the global nature of energy issues and the necessity of international collaboration.

(8) Enhancing interdisciplinary thinking. Taking CCUS, shale gas, and coalbed methane prediction as examples, it reflects the vital role of multidisciplinary collaborative research in breaking through bottlenecks in complex geological evaluation, and cultivates systematic thinking and integrated innovation capability of students.

After establishing the themed resource library, the team further explored the precise docking of ideological elements with professional knowledge points, aiming to cultivate students with both moral integrity and professional competence and integrate knowledge with practice. Taking the six major elements of hydrocarbon accumulation—source, reservoir, cap rock, trap, migration, and preservation—as the carrier, ideological connotations such as energy security, craftsman spirit, and interdisciplinary awareness are subtly embedded into professional teaching. For example, when introducing the source rocks, it highlights the fundamental role of “generation” and guides students to attach importance to basic research. In teaching reservoirs, it embodies the craftsmanship spirit of striving for perfection. For cap rocks, it emphasizes the restraining function of “sealing”, analogizing the awareness of rules and bottom-line thinking. In interpreting traps, it expounds the correlation between opportunity and preparedness. In hydrocarbon migration, it stresses the dynamic evolutionary process and inspires students to grasp the law of development. On preservation conditions, it advocates perseverance and academic inheritance across time scales.

5. Interdisciplinary Collaboration and Teaching Mode Innovation

Energy Geology is an interdisciplinary discipline designed to serve the cultivation of composite professionals with a multidisciplinary perspective [7]. The geology teaching team of Chongqing University promotes curriculum construction and talent training from two dimensions: interdisciplinary collaboration and innovative teaching forms.

5.1 Collective Lesson Preparation and Multidisciplinary Teacher Collaboration

To address the inherent interdisciplinarity of energy geology, our team established a permanent system for collaborative lesson planning. Ahead of each semester, the course director convenes a core group of teachers from fields including geology, geophysics, mining and petroleum engineering, and environmental science. Their joint planning focuses on four key areas: 1) aligning curriculum with students’ specific research interests for highly tailored instruction; 2) integrating diverse disciplinary viewpoints to ensure teaching materials remain complete and cutting-edge; 3) collaboratively leveraging scientist success stories and technological breakthroughs to bolster moral and ethical education resources; and 4) developing innovative teaching strategies to enhance graduate students’ research and practical capabilities.

In the classroom, we have pioneered a co-teaching model. For complex, multifaceted topics like CCUS and shale gas “sweet spot” evaluation, two or three instructors from different fields present together. This multi-perspective approach guides students in building a multidimensional thinking framework. For example, a session on shale gas geography features a geologist explaining formation and enrichment, a geophysicist detailing identification technique, and a petroleum engineer presenting on the integrated geo-engineering approach to drilling and hydrofracturing. This provides students with a firsthand understanding of how to apply multidisciplinary collaboration to solve critical industry problems.

5.2 Exploration and Practice of Diversified Teaching Forms

While strengthening interdisciplinary collaboration, the team actively innovates teaching formats and establishes a diversified teaching framework combining classroom lecture, thematic seminar, flipped teaching, and extracurricular practice.

In systematic lectures, enlightening questions are raised to stimulate the inquiry interest of students, such as Why is the Sichuan Basin the main area of shale gas exploration and development in China? And what geological and environmental risks may exist in hot dry rock exploitation?

Thematic seminars focus on frontier hotspots of energy geology. Students are guided to review literature, summarize progress, form viewpoints, and give oral presentations. Typical topics include development trends of Energy Geology under carbon neutrality and the impact of the shale gas revolution on China's energy pattern, enabling students to integrate theoretical knowledge with national energy strategic needs through active exploration.

Flipped teaching selects specific knowledge modules for students to take the lead in presenting. Working in groups under the guidance of the teacher, students complete the entire process of lesson preparation, trial lecturing, formal presentation, Q&A, and receiving teacher feedback. This practice improves their literature reading, logical thinking, and expression capabilities, and cultivates team spirit.

Relying on geological resources around Chongqing, as well as university research platforms, diversified extracurricular practice activities are designed. Students are organized for field investigations at typical petroliferous sections in the Sichuan Basin to observe source-reservoir-cap assemblages and trap types. They also visit unconventional oil and gas research centers and shale gas demonstration zones to learn cutting-edge technologies and engineering practices. In addition, students are encouraged to participate in research projects of supervisors, to apply professional knowledge, identify scientific problems, and develop research competence in real academic scenarios.

5.3 Reform of Learning Evaluation Methods

Alongside innovative teaching, the teaching team has simultaneously carried out the reform of learning evaluation. It abandons the traditional single assessment mode determined solely by a final examination and establishes a diversified evaluation system combining formative assessment and summative assessment. The proportion of regular academic performance is raised to 50%, including classroom participation (10%), performance in thematic seminars (20%), quality of flipped classroom presentation (10%), performance in practical Q&A (10%), and completion of thematic reports (50%). The evaluation focuses on in-depth understanding and comprehensive application of core knowledge, and promotes the integration of geological thinking and professional training.

6. Conclusion and Outlook

After years of practice, the Energy Geology teaching reform for mining postgraduates at Chongqing University has achieved initial positive effects. Students highly recognize the "conventional energy – unconventional energy – non-fossil energy" trinity curriculum system, and the course evaluation score has steadily improved, ranking in the top 1% in the department for two consecutive years. Diversified teaching forms, including "multi-teacher co-teaching", flipped classroom, and extracurricular practice, are popular among students, effectively enlivening classroom atmosphere and deepening teacher-student interaction. The ideological resource library has strengthened student value recognition of the course and major, improved their acceptance of mining majors, and enhanced their willingness to pursue doctoral studies or enter the energy industry. Comprehensive abilities of postgraduates have been significantly improved, with outstanding performance in academic competitions and paper publications, and some projects have won higher awards. Meanwhile, the collective lesson preparation and collaborative teaching mechanism have broadened the horizons of teachers, promoted their professional growth, and formed a well-structured, collaborative, and innovative teaching team, laying a solid foundation for the sustainable development of the course.

Looking ahead, with accelerated energy transition and in-depth implementation of national energy security and the dual-carbon goals, cultivating high-level mining talents is crucial for the high-quality development of the energy industry. The geology teaching team of Chongqing University will keep pace with disciplinary frontiers and national needs, deepen the integration of curriculum ideological education and interdisciplinary collaboration, and strive to cultivate more energy development talents who can contribute to national energy security and the dual-carbon strategy.

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