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AI-EMPOWERED TEACHING REFORM AND PRACTICAL PATH EXPLORATION FOR THE "GEOLOGY" COURSE

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Abstract: In response to the prevalent issues in traditional geology instruction—namely, the abstract nature of theoretical content, the limited relevance to safety engineering practices, and the insufficient alignment with the talent development demands of intelligent mining engineering—this study focuses on the emerging trends of intelligent mining and geological digitization. It investigates the reform of geology course teaching empowered by artificial intelligence. The proposed reform restructures the course content system, integrates AI technologies to innovate pedagogical models, introduces AI-based intelligent mineral generation techniques, and implements virtual mineral cognition experiments, thereby addressing the deficiencies in traditional experimental teaching resources. By establishing an intelligent teaching system and innovative experimental projects, the conventional rote-teaching model has been effectively transformed, resulting in notable improvements in classroom teaching quality and students' knowledge internalization efficiency. Students' competencies in intelligent geological analysis, accurate disaster assessment, and innovative mining engineering practices have been strengthened, alongside enhanced innovative thinking and overall professional proficiency. This reform aligns with the objectives of intelligent mining talent cultivation and offers valuable reference and insights for the intelligent teaching reform of geology courses in mining-related disciplines.
Keywords: Geology; AI empowerment; Teaching reform; Experimental teaching; Talent cultivation

1 INTRODUCTION

"Geology" is a fundamental required course for mining-related majors, including safety engineering and intelligent mining engineering, and serves as a critical theoretical foundation for students' future engagement in mine exploitation and urban infrastructure construction [1]. The core teaching objective of this course is to comprehensively cultivate students' integrated geological engineering capabilities and practical innovation abilities, enabling them to proficiently master geological fundamentals and surveying methods, identify and analyze various geological hazards in engineering sites, and solve practical geological problems encountered in mining and construction projects, thereby establishing a solid foundation for subsequent professional studies and career development [2]. However, the traditional teaching model of geology currently exhibits considerable deficiencies and limitations. At present, classroom instruction relies predominantly on monotonous methods such as theoretical lectures and graphic presentations, resulting in rigid and uninspiring pedagogical approaches. Moreover, certain abstract and extensive geological knowledge is difficult to convey effectively through conventional teaching means, causing students' knowledge acquisition to remain at a superficial memorization stage. This hinders the effective integration of theory with practical engineering applications and constrains the development of engineering application skills and problem-solving abilities [3].

In recent years, with the increasing maturity of artificial intelligence (AI) technology, AI has been extensively integrated into the education sector. AI in education has evolved from single-tool applications to large-scale, routine human–machine collaborative teaching models, emerging as a core driver of educational digital transformation [4]. In practical applications, AI has established a mature educational service system. AI teaching platforms can leverage powerful algorithms to collect and accurately analyze students' learning behavior data throughout the entire process—including pre-class preparation, in-class learning, and post-class exercises—thereby dynamically identifying students' knowledge gaps and learning habits [5-6]. For students, adaptive learning systems can deliver personalized content, while tools such as intelligent grading, virtual teaching assistants, and immersive virtual experiments effectively enhance learning efficiency. For teachers, AI can automate repetitive tasks such as lesson preparation, classroom performance monitoring, and batch assignment grading, significantly reducing workload and improving efficiency, thus supporting precision teaching [7]. Additionally, AI can intelligently analyze students' learning data, helping teachers accurately grasp overall learning conditions, scientifically optimize instructional design, adjust key teaching points, improve experimental teaching methods, and enhance classroom teaching efficiency and overall teaching quality, thus comprehensively facilitating the implementation of intelligent precision teaching [8].

Meanwhile, artificial intelligence technology has extensively penetrated the fields of geology and mining. AI has demonstrated significant advantages in dynamic prediction of geological hazards, intelligent recognition of mining rock mass structures, precise assessment of mining risks, and intelligent analysis of geological data, with numerous breakthrough application achievements [9]. Therefore, deeply integrating AI technology with geology course teaching and innovating traditional teaching models represents a crucial pathway to overcoming teaching bottlenecks, improving course quality, and cultivating high-quality innovative professionals suited to the development of intelligent mining.

This paper focuses on the current status and existing challenges in "Geology" course teaching, with an emphasis on the deep application of AI in teaching content reform. The reform and practice of AI-empowered geology teaching are carried out at the School of Mining Engineering, Guizhou Institute of Technology, aiming to enhance the teaching level of "Geology" and provide practical reference for similar course reforms.

2 ANALYSIS OF REFORM NEEDS FOR THE TRADITIONAL "GEOLOGY" CURRICULUM

Combining the concept of new engineering education with the talent cultivation orientation of the intelligent mining industry, it is of considerable practical significance to optimize and reform the curriculum system based on artificial intelligence technology, in response to the current teaching shortcomings in geology courses for safety engineering and intelligent mining engineering majors. Traditional theoretical teaching mainly relies on static graphic and textual materials, which cannot visually demonstrate the dynamic processes of geological structure evolution, mineral rock structure characteristics, or geological hazard development. Students find it difficult to construct a complete spatial geological cognition framework, and the effectiveness of knowledge internalization remains suboptimal. At the practical teaching level, traditional instruction primarily depends on limited solid mineral specimens, static images, and simple geological models. There are inherent defects such as limited specimen types, difficulty in observing microscopic features, and an inability to dynamically reproduce geological evolution processes. It is also challenging to replicate the complex geological environment and hidden geological safety hazards of mining areas. Consequently, the geological knowledge acquired by students tends to be fragmented and superficial. Therefore, deeply integrating AI technology into geology course teaching is not only an inherent requirement for implementing the cross-disciplinary integration concept of new engineering disciplines, but also an inevitable trend for adapting to the development of intelligent mining and cultivating high-quality applied talents in mining. AI-empowered teaching can effectively break through the limitations of traditional instruction, focus on cultivating students' abilities in geological structure recognition, geological hazard prediction, and risk analysis, comprehensively enhance the engineering practice ability, innovative competence, and career competitiveness of safety and mining students, and provide reference for the digital course reform and innovative engineering talent cultivation in safety and mining fields.

3 EXPLORATION OF AI-EMPOWERED TEACHING REFORM PRACTICES FOR THE "GEOLOGY" COURSE

3.1 Course Objective Construction and Content Optimization

"Geology" is a foundational course in safety engineering that supports disaster prevention and risk assessment. Accurate assessment of geological hazards constitutes a key scientific basis for ensuring safe production. In the context of new engineering discipline construction, based on the core needs of talent cultivation for geological disaster prevention and control and engineering safety risk management in the safety engineering field, and guided by the Outcome-Based Education (OBE) concept, we have constructed the course objectives and content system for "Geology" for safety engineering and intelligent mining engineering majors, deeply integrated with AI-assisted technology. The aim is to cultivate interdisciplinary talents who not only master geological expertise but also possess safety competencies. In the new era, safety engineering talents in Guizhou require not only solid professional knowledge and skills such as identifying geological hazards, evaluating soil stability, and judging hydrogeological conditions, but also an in-depth understanding of geological hazards in karst landforms. They should firmly establish the concept of "safety first, safe development" and actively engage in the broader practice of national ecological civilization and safe production in the new era.

3.1.1 Restructuring course objectives

By benchmarking the graduation requirements indicators for engineering education certification and the requirements of industry positions, and combining these with the actual needs of the industry, the course objectives have shifted from traditional knowledge transmission to a three-dimensional goal system covering knowledge, abilities, and professional competence. At the knowledge objective level, students are required to systematically and proficiently master the basic theories of geology, relevant safety regulations, and engineering technical methods in the mining industry, thereby building a complete and solid professional knowledge framework. At the ability objective level, emphasis is placed on cultivating students' engineering practice and application abilities, encouraging them to flexibly apply professional theories to solve complex geological engineering problems in mines, and ensuring that students can independently carry out professional work such as mining geological exploration, geological hazard analysis, and risk assessment within 3–5 years after graduation, meeting key professional requirements. At the level of professional literacy goals, emphasis is placed on cultivating students' comprehensive professional competence, guiding them to establish rigorous and scientific engineering values and adhere to bottom-line professional ethics, while exercising their teamwork and effective communication abilities, and maturing into versatile engineering talents that meet the demands of industry development.

3.1.2 Optimization of teaching content

To further optimize the teaching system of geology courses and meet the practical needs of talent cultivation in safety engineering and intelligent mining, it is necessary to systematically adjust the existing content and structure of the courses. The course will focus on incorporating teaching content related to the latest developments in the safety industry, introducing new cases relevant to on-site conditions such as mining geological disasters and mining ecological pollution.

Through real and typical case-based teaching, we address the problem of traditional theoretical teaching being disconnected from field practice, making the teaching content highly relevant to actual working scenarios in mines. This expands students' professional knowledge and industry perspectives, helps them stay updated with the latest industry developments, and enhances their adaptability to safe mining positions. At the same time, relying on artificial intelligence technology, we comprehensively innovate teaching forms and enrich three-dimensional teaching resources, effectively compensating for the deficiencies of traditional classroom teaching. While consolidating students' basic geological knowledge, this approach effectively broadens their professional knowledge and industry perspectives, helps students keep pace with the latest advances in intelligent mining and mining safety in real time, and enhances their adaptability to mining positions and engineering practice abilities. Through the deep integration of AI digital teaching methods and the combination of theory with real-life teaching scenarios, we aim to comprehensively cultivate students' professional practical abilities, engineering innovation thinking, and overall professional qualities. This aligns with the goals of intelligent, safe, and green modern mining talent cultivation, and lays a solid teaching foundation for the cultivation of high-quality applied talents in intelligent mining and safety engineering in the new era.

3.2 Design of AI-Assisted Course Teaching Methods

To adapt to the training objectives of safety engineering and intelligent mining engineering professionals, and to meet the actual needs of the mining safety prevention and control industry, we rely on artificial intelligence technology to optimize the teaching mode of geology courses from three dimensions: personalization, visualization, and scenario-based approaches. This effectively addresses the shortcomings of traditional teaching and comprehensively improves teaching quality and students' professional abilities.

3.2.1 Implementing personalized smart teaching

Personalized smart teaching is a core measure to improve teaching precision. Relying on the AI learning intelligence analysis system, we comprehensively collect students' entire learning process data, including pre-class preview tests, real-time in-class quizzes, and post-class homework assignments. We accurately identify and analyze students' weak points in core knowledge areas such as mining geological structure recognition, geological disaster mechanisms, and geological safety data analysis. The system combines each student's knowledge reserve and learning ability differences to automatically generate hierarchical and customized learning paths, and constructs a closed-loop teaching system that intelligently pushes geological safety preview resources before class, provides precise answers to key and difficult questions during class, and consolidates specialized exercises after class. This completely transforms the traditional homogeneous teaching mode, fully mobilizes students' autonomous learning enthusiasm, and greatly improves the learning efficiency of mining geological safety knowledge.

3.2.2 Carrying out scenario-based safety case teaching

Scenario-based safety case teaching focuses on cultivating engineering application abilities. With the help of an AI big data resource library, typical cutting-edge cases of mining geological disasters, underground safety hazard control, and geological risk assessment are selected, and immersive teaching is conducted in combination with mining technology and safety regulations. By deeply integrating geological theory with mine risk assessment, disaster prevention and control, and safety governance, students can immerse themselves in the formation mechanisms of geological disasters, effectively enhancing their engineering analysis and safety response capabilities, and meeting the needs of cultivating interdisciplinary innovative talents for mine safety in the new era.

4 AI-ASSISTED GENERATION OF MINERAL RECOGNITION EXPERIMENTAL TEACHING CASES

4.1 Analysis of the Current Situation of Experimental Teaching

In traditional geological experimental teaching, there are difficulties such as insufficient solid mineral specimens, lack of experimental equipment, absence of rock thin sections, and shortage of microscope equipment. Traditional teaching of mineral knowledge can only rely on static pictures in textbooks. These images are limited in variety, fixed in perspective, and overly idealized in their representation. Students cannot distinguish the real differences in mineral crystal shape, luster, cleavage, and aggregate morphology. They lack intuitive understanding of the three-dimensional characteristics, appearance variations, and alteration forms of minerals, and are prone to problems such as conceptual ambiguity, mineral misidentification, and mixed feature memorization. To address this teaching deficiency, AI virtual mineral generation technology is adopted instead of physical specimen experiments. Various rock-forming minerals are generated through artificial intelligence from multiple angles, in multiple forms, and with high realism, allowing students to break free from the limitations of single planar images and comprehensively understand mineral characteristics from three-dimensional appearance, different phases, and different occurrence states. This effectively enhances students' cognitive ability to understand the macroscopic characteristics, appearance differences, and morphological changes of common minerals.

4.2 Implementation of Experimental Teaching

Experimental teaching relies on AI 3D reconstruction and dynamic visualization technology to create a typical mineral intelligent cognitive interactive experimental system, breaking down the physical observation barriers of traditional mineral experiments. In the form of three-dimensional modeling images, the complete crystal structure of standard minerals can be restored, and target mineral models can be intelligently generated according to students' learning needs, clearly presenting the morphological characteristics of various minerals such as quartz, feldspar, mica, calcite, and pyrite. In the practical training stage, students can rely on the intelligent interactive platform to carry out independent exploratory learning: on the one hand, they can choose to use AI 3D reconstruction to generate virtual mineral models such as quartz, pyrite, and calcite, and use digital interactive operations such as scaling and rotation to zoom in and observe crystal texture, cleavage cracks, internal microstructure, and other details layer by layer, achieving multi-angle and all-round fine feature cognition of a single mineral; on the other hand, multiple sets of virtual mineral models can be loaded for synchronous comparison and display on the same screen. Special comparative analysis can be carried out to clarify the essential differences between quartz and calcite—which are similar in appearance and easily confused by students using the naked eye—in terms of crystal morphology, cleavage development degree, optical appearance, and other identification indicators. Through the systematic training process of observing mineral characteristics, comparing similarities and differences, distinguishing categories, and performing comprehensive identification, students can effectively enhance their ability to systematically identify minerals. AI-assisted generation of minerals is shown in Figure 1 (a)-(b).

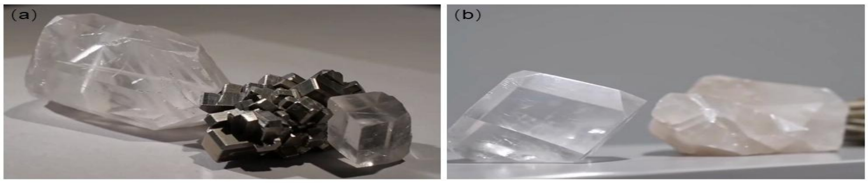

Figure 1 (a) AI Assisted Generation of Pyrite and Quartz Crystals; (b) AI Assisted Generation of Quartz and Calcite Crystals

5 CONCLUSIONS

This paper, grounded in the practical needs of talent cultivation in the fields of safety engineering and intelligent mining, relies on artificial intelligence technology to carry out systematic optimization and reform innovation of the teaching system, effectively solving problems such as outdated traditional teaching content, disconnection between theory and field practice, and abstract and difficult key points. The introduction of AI mineral intelligent generation technology to conduct virtual mineral cognition experiments has filled the gaps in experimental teaching, improved the experimental teaching system, and enhanced the intuitiveness and effectiveness of both theoretical and practical instruction.

Through the deep integration of AI technology with classroom teaching and experimental training, the course has achieved a transformation from traditional passive indoctrination teaching to active inquiry-based learning for students. While consolidating students' geological foundational theory, this reform comprehensively enhances their innovative thinking and overall professional competence. This educational reform effectively meets the needs of intelligent mining talent cultivation and can provide a good reference and demonstration for the digital and intelligent teaching reform of geology courses in mining-related majors.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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