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Reconstruction of the Teaching Practice System for Underground Space Engineering Construction Technology from the Perspective of Emerging Engineering Education

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Abstract: The development of emerging engineering education imposes an urgent requirement on engineering education to shift from a discipline-oriented paradigm to an industry demand-driven one. As a critical field supporting urban sustainable development, urban underground space engineering faces three major dilemmas in its construction technology teaching: teaching content lags behind industrial technological iteration, practical teaching is constrained by the concealment and high risk of engineering projects, and teaching resources are fragmented with insufficient integration of ideological and political education. Based on the practical exploration of an emerging engineering education reform project at a university, this paper proposes an integrated teaching system characterized by "case guidance, technology empowerment, industry-education integration, and ideological-political penetration throughout the process". Centered on the reconstruction of modular teaching content, supported by a multi-scenario practical teaching platform, and guaranteed by collaborative education via industry-education integration, this system embeds ideological and political education throughout the entire process of knowledge impartation and competence cultivation. It aims to cultivate underground engineering talents for the new era with solid theoretical foundations, excellent engineering practice capabilities, and noble professional qualities.

Keywords: **Emerging Engineering Education; Underground Space Engineering; Curriculum-Based Ideological and Political Education; Intelligent Construction; Industry-Education Integration; Teaching Practice System**

1. Introduction

The emerging engineering education initiative is a major educational reform measure launched by the state to proactively respond to the new round of scientific and technological revolution and industrial transformation. The Ministry of Education explicitly states that engineering education should proactively orient toward the future, the industry, and the world, and promote the transformation of talent cultivation from discipline orientation to industry demand orientation, and from siloed specialties to cross-disciplinary integration [1-3].

As an important branch of civil engineering, urban underground space engineering undertakes the disciplinary mission of providing underground infrastructure support for sustainable urban development [4]. At present, the scale of development and utilization of urban underground space in China continues to expand. Projects such as tunnels, subways, utility tunnels, and underground complexes demonstrate a development trend of "large-scale deployment, networked layout, deep-level exploitation, and intelligent operation", and the industry maintains a strong demand for high-quality professional and technical personnel. However, in sharp contrast to the rapid development of the industry, the traditional teaching system of underground space engineering construction technology is confronted with a series of structural dilemmas [5,6]. First, the updating speed of teaching content lags far behind industrial technological iteration, and intelligent technologies such as Building Information Modeling (BIM), Geographic Information System (GIS), and artificial intelligence have not been systematically integrated into the curriculum system. Second, practical teaching is restricted by the high concealment and high risk of underground engineering, making it difficult for students to obtain sufficient on-site hands-on opportunities. Third, the development of curriculum-based ideological and political education is generally superficial, failing to achieve deep integration of value guidance and knowledge impartation [7,8].

How to reconstruct the teaching system of underground space engineering construction technology from the perspective of emerging engineering education and realize the dual driving force of ideological-political guidance and intelligent empowerment has become a critical issue to be addressed urgently [9-11]. Based on the practical exploration of a teaching reform project for the urban underground space engineering program at a university, this paper systematically elaborates the reconstruction ideas of the teaching practice system from three dimensions: dilemma analysis, theoretical logic, and implementation path, so as to provide references for peer institutions.

2. Three Major Dilemmas in Teaching Practice

2.1 Structural Lag between Technological Iteration and Teaching Content

Underground space engineering construction technology is undergoing a profound transformation from traditional construction methods to intelligent and digital directions. The integrated BIM-GIS technology has enabled three-dimensional visualization of geological information and intelligent evaluation of underground space. Intelligent monitoring systems, relying on the Internet of Things (IoT), have realized real-time perception and early warning of high-risk working faces. The combination of numerical simulation and machine learning technology empowers data-driven optimization of construction schemes under complex conditions.

However, most of the aforementioned cutting-edge technologies only appear as introductory content in existing textbooks and curriculum systems, lacking systematic integration and in-depth practical modules. Taking shield construction technology teaching as an example, current textbooks provide detailed elaboration on the basic structure of shield machines, but devote very limited attention to cutting-edge content such as intelligent tunneling systems, automatic guidance technology, and digital segment assembly, and rarely involve the application of BIM technology in construction simulation and schedule control. Although students can recite construction procedures, they lack understanding of core technologies such as digital construction management and intelligent monitoring. This structural lag leads to a significant "technology gap" between what students learn and what the industry applies.

2.2 Inherent Contradiction between Engineering Attributes and Practical Teaching

Underground space engineering construction features prominent characteristics such as high concealment, high risk, high investment, and irreversibility. Accidents in deep foundation pits can cause severe consequences, and surface settlement control is extremely demanding when shields pass through existing buildings and structures. These characteristics determine that core construction working faces are difficult to open to students on a large scale. It is hard for students to frequently enter key areas such as the bottom of deep foundation pits and shield tunneling faces for observation and hands-on operation, resulting in a lack of intuitive and in-depth understanding of construction technology selection, parameter regulation logic, and key points of risk management under complex conditions. Meanwhile, ideological and political elements such as engineering ethics and safety responsibility embedded in links like on-site safety briefing and quality inspection can hardly be effectively internalized into students' professional quality through limited teaching exposure.

2.3 Fragmentation of Teaching Resources and Superficial Ideological-Political Integration

Existing teaching resources present obvious fragmentation, lacking systematic and digital integration. BIM software and virtual simulation resources are often isolated and scattered, failing to form an organic whole with engineering cases, teaching objectives, and ideological-political education tasks. Students frequently operate software divorced from engineering contexts, only completing procedural steps without understanding the value of technical tools in practical decision-making. In terms of curriculum-based ideological and political education, most specialized courses remain at the stage of superficial "labeling-style" accumulation of ideological and political elements, lacking deep coupling and systematic design with professional knowledge points. Neither a complete ideological-political content system has been formed, nor effective integration carriers and evaluation mechanisms are available.

The three dilemmas mentioned above are intertwined and mutually reinforcing: technological lag reduces the alignment between practical teaching and industry frontiers; limited practice weakens the perception of technical application; resource fragmentation undermines the overall effectiveness of the teaching system. To break through this dilemma, collaborative reconstruction is required from three dimensions: curriculum content, practice platform, and education mechanism.

3. Theoretical Logic of System Construction

3.1 Reconstruction Logic of the Teaching System under the Emerging Engineering Education Concept

The core proposition of emerging engineering education construction lies in answering the fundamental question of "what kind of talents to cultivate, how to cultivate them, and for whom to cultivate them". Contemporary engineering talents not only need solid professional knowledge and proficient technical skills, but also need to possess systematic thinking, cross-disciplinary integration capability, awareness of engineering ethics, and a sense of social responsibility.

Accordingly, the reconstruction of the teaching system for underground space engineering construction technology should follow the following logic: guided by industrial demand, closely align with cutting-edge industrial technologies to ensure "zero-distance" connection between talent cultivation and industrial employment; take competence cultivation as the main line, and build a step-by-step cultivation path from basic cognition to comprehensive design and then to innovative optimization; take value shaping as the core, so that value guidance runs through the whole process of knowledge impartation and competence cultivation; supported by technology empowerment, and use digital means to break through the limitations of traditional teaching in terms of time and space, safety, and cost.

3.2 Framework Design of "One Core and Three Dimensions"

Based on the above logic, this paper proposes a teaching system framework of "one core and three dimensions". "One core" refers to the trinity education goal of "value shaping – knowledge impartation – competence cultivation"; "three dimensions" refer to modular reconstruction in the teaching content dimension, multi-scenario integration in the practice platform dimension, and school-enterprise collaboration in the education mechanism dimension.

In the teaching content dimension, taking typical construction methods such as the open-cut method and shield method as the core clue, the traditional straightforward chapter-by-chapter organization mode of textbooks is broken, and teaching units are reconstructed around practical engineering problems. Each module covers four components: "theoretical knowledge – technical tools – engineering cases – ideological and political elements", realizing the simultaneous advancement of knowledge impartation, competence cultivation, and value guidance.

In the practice platform dimension, through the organic connection of three scenarios: "physical model cognition – virtual simulation operation – on-site field observation", a spirally ascending practical experience path is formed. Physical models address the cognitive question of "what it is", virtual simulation addresses the operational question of "how to do it", and on-site observation addresses the engineering judgment question of "why it is done this way". The three complement and collaborate with each other, effectively breaking through the teaching limitations of a single scenario.

In the education mechanism dimension, a three-level school-enterprise collaboration paradigm of "resource co-construction – talent co-cultivation – achievement sharing" is constructed, transforming enterprises' advantages in engineering practice into teaching resources, and transforming universities' advantages in theoretical teaching into innovation momentum for enterprises.

3.3 "Three-Stage Integration" Mechanism of Ideological and Political Education

The effective integration of curriculum-based ideological and political education needs to address the issues of "what to integrate, how to integrate, and how to evaluate". This study constructs a "three-stage integration" mechanism. In the cognition stage, red-themed underground engineering cases and stories of tackling key problems in major projects are integrated to guide students to understand the strategic significance of underground engineering construction for national security and stimulate their patriotism. In the practical training stage, students' professional ethics, craftsman spirit, and team awareness are cultivated through engineering ethics scenario discussions, safety specification training, and team-based project practice. In the innovation stage, research topics are set around national strategic demands such as green construction under the "dual carbon" goal and urban resilience and security, to guide students to establish the professional ideal of serving the country through science and technology.

4. Core Implementation Paths

4.1 Reconstruction of the Modular Teaching System

The modular teaching system is progressively developed in three levels: "basic cognition – comprehensive design innovative optimization". The basic cognition module starts from the real case of "deep foundation pit construction of a subway station", and designs cognitive tasks based on geological profiles, construction records and other materials. Students complete the identification of engineering conditions, construction difficulties, and overall schemes through literature review and group discussion, and establish a systematic cognitive framework.

The comprehensive design module requires students to independently propose support and excavation schemes according to survey results, and verify the deformation and stability of retaining structures with the aid of finite element analysis software. It emphasizes the collaborative application of multiple knowledge points and cultivates comprehensive analysis ability.

The innovative optimization module introduces safety risk assessment tasks, requiring students to propose monitoring and control schemes for risks such as foundation pit inrush and excessive building settlement and carry out iterative improvement, so as to stimulate critical thinking and innovation awareness. Each module is equipped with clear ideological and political mapping points, corresponding to "engineering ethics and professional responsibility", "scientific spirit and rigorous work style", and "innovation-driven development and serving the country through science and technology" respectively, realizing the synchronous advancement of competence improvement and value growth.

4.2 Construction of a Multi-Scenario Integrated Practice Platform

Aiming at the practical teaching challenges of high risk and high cost in underground engineering construction, this study constructs a three-in-one platform of "physical model cognition – virtual simulation operation – on-site field observation". In the first scenario, shield machine teaching models are used to guide students to identify core components such as the cutter head, shield body, and propulsion system. Students master equipment principles through hands-on operation, and education on the "national craftsman spirit" is integrated into the process.

In the second scenario, working conditions of shield tunneling through soft-hard heterogeneous strata are constructed based on virtual simulation software. Students independently set tunneling parameters and observe changes in surface settlement, optimize schemes through trial and error, and compensate for the shortage of limited access to real equipment operation. In the third scenario, students are organized to visit school-enterprise cooperation bases for on-site observation of operation links such as shield tunneling and segment assembly. Front-line engineers explain typical problems and countermeasures, and students complete practice reports, focusing on cultivating professional identity.

The three scenarios form a closed loop of "intuitive perception – virtual exercise – on-site verification", effectively improving knowledge transfer and comprehensive judgment ability.

4.3 Mechanism Innovation of Collaborative Education through Industry-Education Integration

Industry-education integration is the key to bridging the "last mile" between talent cultivation and industrial demand. This study constructs a "three-level progressive" school-enterprise collaboration mechanism. At the resource co-construction level, a tutor resource pool is co-built with enterprises, and teaching resource packages of real engineering cases are jointly developed. Enterprise engineers introduce the latest engineering standards into teaching through special lectures, internship guidance, and graduation design review.

At the talent co-cultivation level, the dual-tutor system is systematically implemented for both post internships and graduation design featuring "enterprises setting topics and completing real projects". Students participate in monitoring, data collection and other work in actual projects such as subway shield underpassing buildings. Graduation design focuses on real technical topics from enterprises, and is jointly guided by school and enterprise tutors to form schemes with engineering application value. Schools and enterprises jointly evaluate students' performance in professional ethics and teamwork.

At the achievement sharing level, a closed loop of "teaching – practical application – feedback" is established. Students' research achievements are selectively applied to practical projects after evaluation. Enterprises feed back application effects and new technical problems to the teaching link, forming a virtuous cycle of continuous iterative optimization, and realizing two-way empowerment of education effectiveness and industrial benefits.

5. Reconstruction of the Teaching Evaluation System

Teaching evaluation serves as a critical link for verifying reform effectiveness and guiding continuous improvement. Traditional evaluation overemphasizes knowledge memorization and final examinations, making it difficult to effectively measure students' performance in complex engineering problem-solving, intelligent technology application, and the development of ideological and political literacy. Centering on the core concept of ideological-political guidance and intelligent empowerment, this study reconstructs the teaching evaluation system from three dimensions: evaluation content, evaluation subjects, and evaluation methods.

5.1 Diversified Evaluation Content

The evaluation is divided into three dimensions: knowledge, competence, and literacy. The knowledge dimension assesses basic principles, key points of construction methods, and operation specifications of intelligent tools; the competence dimension evaluates engineering analysis, scheme design, and risk identification capabilities; the literacy dimension examines engineering ethical judgment, sense of responsibility, and professional mission. Each dimension corresponds to the "one core and three dimensions" education goal, ensuring the consistency of teaching – learning – evaluation.

5.2 Collaborative Evaluation Subjects

A four-element collaborative system of teacher evaluation – enterprise evaluation – peer evaluation – self-evaluation is constructed. Teachers focus on professional judgment; enterprise supervisors emphasize practical specifications and professional attitudes; peer evaluation concentrates on individual contribution to the team; self-evaluation guides students to independently examine their learning effectiveness and literacy development. Together, they form an evaluation network featuring mutual complementation and cross-validation.

5.3 Diversified Evaluation Methods

A three-in-one approach of process recording – achievement assessment – reflective evaluation is established. Process recording tracks learning engagement via experimental reports and internship journals; achievement assessment evaluates scheme quality through oral defense and project presentations; reflective evaluation promotes phased summary based on learning reflection reports. For ideological and political assessment, an implicit evaluation strategy embedded in professional evaluation is adopted: ethical considerations, compliance with safety specifications, and awareness of social responsibility are synchronously examined in scheme design, operation assessment, and team presentations, so as to avoid the disconnection between ideological-political education and professional teaching.

The three dimensions operate in coordination to form an evaluation ecosystem aligned with the reconstruction of the teaching system, providing a reliable basis for continuous improvement.

6. Conclusion

The construction of emerging engineering education provides a historic opportunity for engineering education reform. The teaching practice system of "ideological-political guidance and intelligent empowerment" proposed in this study attempts to address the three dilemmas of "technological lag, limited practice, and weak ideological-political education" in traditional teaching through the reconstruction of modular teaching content, the construction of multi-scenario practice platforms, and the innovation of industry-education integration mechanisms.

Its core concept is that technology is a means, while education is the fundamental goal. The introduction of intelligent technology aims to more effectively realize the unity of knowledge impartation, competence cultivation, and value guidance; the integration of ideological and political education represents the value return of the essence of engineering education; the deepening of industry-education integration is a fundamental transformation of the talent cultivation paradigm from "university-led" to "school-enterprise co-governed".

Looking forward, underground space engineering education requires continuous exploration: establishing a long-term mechanism for synchronous updating of teaching content and industrial technologies, promoting the transformation of ideological and political education and specialized teaching from "physical superposition" to "chemical reaction", building a more open industry-education integration ecosystem, and upgrading enterprises from "participants" to "co-builders", so as to truly cultivate outstanding engineers of the new era who can undertake the great mission of national rejuvenation.

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