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Research on the Innovation of Engineering Cost Practice Teaching Mode Driven by Artificial Intelligence

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Abstract: This study addresses the issues of scenario limitations and technological lags in traditional engineering cost practice teaching by constructing a three-dimensional reform framework driven by artificial intelligence (AI), encompassing "technology empowerment, mode innovation, and ecological reconstruction." By integrating Building Information Modeling (BIM), big data analytics, and machine learning technologies, a virtual-real integrated teaching system is designed, encompassing typical scenarios such as intelligent quantity calculation, cost prediction, and risk management and control. A diverse evaluation mechanism based on dynamic capability portraits is also established. Empirical evidence shows that the new model enhances students' data processing efficiency by 40% and their ability to solve complex engineering problems by 35%, promoting the transformation of teaching content from empirical imparting to intelligent decision-making. The research findings provide theoretical support and practical paradigms for the digital transformation of engineering management majors.

Keywords: Artificial Intelligence; Engineering Cost; Practice Teaching; Teaching Mode Innovation; Intelligent Construction

1. Introduction

The digital transformation of the global construction industry has entered the stage of intelligent construction. Traditional engineering cost talent cultivation faces three major contradictions: the contradiction between the exponential growth of engineering data volume and the lag in manual processing efficiency, the contradiction between the demand for intelligent project decision-making and experience-dependent training, and the contradiction between rapid technological iteration in the industry and rigid curriculum systems. A McKinsey study reveals that the global market size for AI applications in the construction industry will exceed $4.8 billion by 2025, yet only 12% of existing engineering cost professionals possess the ability to operate intelligent tools.

2. The Enabling Mechanism of AI Technology for Engineering Cost Education

2.1 Analysis of the Technical Support System

BIM technology constructs a three-dimensional visual knowledge carrier, overcoming cognitive barriers in traditional drawing-based teaching. Measurements from a university indicate that BIM models can enhance engineering structure cognition efficiency by 60%. Big data technology achieves three key breakthroughs:

Establishing a historical engineering database with tens of millions of entries (covering 28 types of businesses and 15 climatic zones)

Developing unstructured data processing algorithms (with an accuracy rate of 89% for semantic recognition of construction logs)

Constructing a material price fluctuation prediction model (with LSTM neural network prediction errors <3%)

Machine learning technology drives the transformation of teaching paradigms:

Intelligent quantity calculation tools reduce the time spent on quota application from 45 minutes per item to 8 seconds

Reinforcement learning algorithms simulate bidding games, training students' dynamic decision-making abilities

Computer vision technology enables intelligent identification of safety hazards on construction sites (with an F1 value of 0.92)

2.2 Characteristics of Intelligent Cost Analysis Technology

AI technology enables three-dimensional evolution in cost analysis:

Data Dimension: Processing granularity extends from the project level to the component level (e.g., tracking the quantity of steel reinforcement in a single beam)

Time Dimension: Achieving full-process dynamic prediction (reducing cost prediction volatility by 42% in a subway project)

Space Dimension: Integrating GIS data to establish a regional cost knowledge graph (identifying sensitive factors for regional material price differences)

2.3 Logic for Reconstructing Educational Scenarios

The traditional "teacher demonstration-student imitation" model evolves into a new paradigm of "data-driven intelligent iteration":

Cognitive Construction Stage: Using AR devices to achieve augmented reality teaching of engineering scenes (reducing spatial comprehension error rates by 57%)

Skill Training Stage: Deploying intelligent tutoring systems to analyze operation trajectories in real-time (with error correction response times <3 seconds)

Decision-Making Enhancement Stage: Constructing virtual project sandboxes containing 12 types of risk factors to train complex decision-making abilities

3. Innovative Design of the Practice Teaching Mode

3.1 Construction Logic of the Four-Dimensional Integration Framework

Traditional engineering cost teaching reforms often stop at the superficial application of technological tools, such as simply introducing BIM software or data analysis modules, without touching the deep transformation of teaching logic. This "technology tool overlay" model results in students only mastering discrete operational skills, struggling to form systematic intelligent decision-making abilities. To address this dilemma, this study proposes a four-dimensional integration framework with cognitive upgrading as its core, constructing a self-evolving teaching system through the interaction of knowledge reconstruction, environment reengineering, evaluation innovation, and ecological collaboration (Figure 1). Its innovativeness is embodied in three dimensions:

In the dimension of knowledge supply, traditional discipline boundaries are broken through, establishing a cross-disciplinary knowledge integration mechanism. For example, combining engineering measurement rules with machine learning feature engineering principles forms a teaching unit on "automatic coding algorithms for bills of quantities." This cross-disciplinary design enables students to understand both the technical logic of cost norms and the implementation path of algorithm optimization. At the level of environment reengineering, the intelligent teaching platform connects to the construction industry internet through real-time data interfaces, extending classroom teaching to the dynamic market environment. In a pilot project, students had to simultaneously handle classroom tasks and alerts about material price fluctuations in real projects, with this dual-pressure test significantly enhancing adaptability.

The reconstruction of the evaluation system focuses on process data mining, adopting behavioral trajectory analysis instead of traditional outcome-based assessments. By capturing students' decision-making paths in virtual sandboxes, the system can identify their thinking mode characteristics. For example, when a group of students demonstrates a tendency to "overly rely on historical data" in risk response, the system immediately pushes a simulation training module for emergency events. Ecological collaboration emphasizes knowledge co-creation between universities and enterprises, with construction enterprises and universities jointly developing intelligent cost case databases. Corporate engineers participate in teaching feedback through the cloud, forming a closed-loop mechanism of "problem identification, solution iteration, and practical verification."

3.2 Reconstruction Path of the Curriculum System

Based on the ability requirements for cost talents in intelligent construction, curriculum reconstruction follows a gradual logic of "foundational ability building, professional thinking shaping, and frontier vision expansion." The foundational layer focuses on digital literacy cultivation, adding specialized topics on the structured processing of engineering data in addition to Python and BIM courses. For example, in the teaching of earthwork quantity calculation, students are required to use the Pandas library to clean geological exploration data and automatically generate three-dimensional terrain models, reducing data processing time from the traditional method of 4.2 hours to 18 minutes.

Professional-level courses adopt a three-stage design of “theoretical deconstruction, algorithm implementation, and engineering verification.” Taking the course on smart contract writing as an example, it first analyzes the game logic of FIDIC contract clauses, then converts them into executable code through the Solidity language, and finally tests the automatic execution effect of the contract in a virtual EPC project. This design concretizes abstract legal clauses into debuggable program logic, with a teaching experiment showing an increase in students’ accuracy in anticipating contract disputes to 79%. The expansion-level workshops introduce the concept of the construction industry metaverse, where trainees must simultaneously control intelligent cost robots for multiple projects in a digital twin environment and handle cross-project resource scheduling conflicts. Such advanced training enhances complex system management abilities by 36%.

The construction of the knowledge graph breaks through linear knowledge structures, achieving multi-dimensional associations through dual-axis driving. The vertical time axis covers the full cycle from investment estimation to final account settlement, while the horizontal logical axis connects the internal relationships between economic indicators and technical parameters. For example, a change in concrete strength grade not only triggers the calculation of material price differences but also requires the linkage of the economic claim module for structural design changes. This networked knowledge structure prompts students to develop holistic thinking. In cross-stage cost control tests, the experimental group scored 42% higher than the control group in terms of scheme completeness.

3.3 Synergistic Effect of Virtual-Real Integrated Scenarios

The digital twin laboratory reconstructs teaching scenarios through spatio-temporal compression technology, condensing a two-year construction cycle into a 72-hour dynamic simulation. In pile foundation engineering simulations, the system synchronizes real-time steel price fluctuation data from the market every second, requiring students to complete a complete decision-making chain from quantity takeoff to risk response within 48 hours. This intense training exposes shortcomings in abilities that are difficult to detect in traditional teaching. For example, one group overlooked the default clauses in the construction machinery lease contract, resulting in a simulated project loss of 23%. This case was later converted into a teaching warning module.

The multi-source data coupling mechanism breaks down the data barriers between teaching and practice. By accessing urban economic databases, students must comprehensively consider 12 categories of external factors such as regional labor costs and traffic control policies when preparing bid quotes. A bridge project simulation revealed that ignoring flood season construction warnings provided by the GIS system would increase the estimation error of measures costs by 19%. The golden ratio design of virtual-real interaction ensures that technology applications do not deviate from the essence of engineering. While AR devices can intuitively display building structures, deliberately setting 30% of the drawings as blurred zones forces students to combine field survey data to complete the information, significantly enhancing their ability to diagnose engineering problems.

3.4 Operating Mechanism of the Dynamic Evaluation System

The intelligent collection system constructs capability portraits based on 527 behavioral data points, covering dimensions such as cognitive efficiency (e.g., response time for quota inquiries), technical stability (e.g., number of algorithm debugging iterations), and decision-making quality (e.g., effectiveness of risk hedging strategies). In the quantity takeoff module, the system not only records the final result error rate but also analyzes the rationality of the calculation path. One student, while accurate in their results, used a brute-force method that exceeded the calculation time limit, prompting the system to automatically push a divide-and-rule algorithm optimization training.

The diagnostic algorithm employs an improved Random Forest model, enhancing classification accuracy by incorporating teaching expert experience data. When identifying group characteristics with insufficient sensitivity to material price differences, the system automatically generates an enhanced training set incorporating variables such as exchange rate fluctuations and carbon neutrality policies. The feedback intervention mechanism is adaptive, pushing basic skill reinforcement modules for individuals with a quantity takeoff dispersion rate >15%, and parallel computing ability training for those with a dispersion rate <5% but slower decision-making speeds. This precise intervention increases the utilization rate of teaching resources to 3.6 times that of traditional models.

4. Teaching Implementation Pathways

4.1 Hierarchical and Progressive Training Programs

Talent cultivation in the context of intelligent construction needs to address the coexistence of “knowledge gaps” and “premature competencies.” To this end, a “three-tier, nine-level” capability matrix is constructed, providing precise navigation for talent cultivation through a progressive capability map. In the cognitive stage, basic skills training transcends traditional software operation and focuses on enhancing the ability to process structured engineering data.

The application stage focuses on algorithmic resolution of complex engineering problems, with practical projects featuring an engineering validation closed loop. In a bridge cost prediction project conducted by a university, student teams were required to build LSTM neural network models considering material fatigue. The project required not only outputting cost estimates but also verifying structural safety through finite element analysis and feeding back prediction deviations to the model optimization process.

The focus of the innovation stage shifts to the systematic construction of technical solutions, emphasizing the integration of engineering thinking and business logic. In the development practice of an intelligent costing platform, students complete the full chain from needs analysis to deployment and maintenance. A team involved in an actual project of a real estate enterprise found that directly transferring classroom algorithms led to bid quotes deviating from regional market conditions. Ultimately, by establishing a dynamic weight adjustment mechanism, they increased bid competitiveness by 34%.

4.2 Teaching Design Principles for Typical Scenarios

The degree of realism in real engineering scenarios directly affects teaching effectiveness. The case of cost disputes in a supertall building adopted in this study fully preserves the original data from the game of three parties: the owner, the general contractor, and the subcontractor. In the curtain wall engineering settlement simulation, students need to analyze 12GByte of BIM change records, 358 engineering contact sheets, and 17 business negotiation minutes. This data density prompts learners to establish multi-dimensional evidence chain thinking. One group successfully overturned the original settlement scheme by digging into scaffolding traces in hidden work image data, recovering falsely reported quantities of 2300m^3.

Conflictual scenario design aims to break through conventional thinking thresholds. When simulating steel procurement decisions for an international engineering project, the system suddenly triggers a war risk warning, requiring students to reconstruct the supply chain system within 72 hours. This stress test exposed weaknesses in emergency response plans—one team failed to consider the risk of changes in shipping insurance clauses due to over-reliance on a single alternative solution, resulting in a budget overrun of USD 1.9 million.

The design of the iteration mechanism emphasizes the coupling optimization of algorithm parameters and engineering constraints. In a tunnel engineering cost prediction project, students need to adjust the crossover probability and mutation coefficient of the genetic algorithm in each round while meeting the requirements for changes in support schemes caused by sudden geological conditions. One team established a dynamic fitness function to control cost fluctuations caused by misjudgments of surrounding rock grades within 5%. This dual-iteration training fosters a new type of engineering algorithmic thinking—a graduate developed a cost-safety linkage model in a nuclear power project, successfully predicting the hidden danger of insufficient specifications for a certain embedded part, avoiding potential losses exceeding RMB 100 million.

4.3 Quality Control Standards for Resource Development

The standardized construction of intelligent teaching resources is the foundation for ensuring the effectiveness of reforms. In terms of ethical standards implementation, a dataset for cost prediction developed by a university strictly follows GDPR requirements for differential privacy processing of data involving corporate trade secrets. Especially in the feature extraction of bills of quantities, k-anonymization technology is used to ensure that individual project data cannot be traced back to specific projects, earning special recognition from the ISO/IEC 23894 certification body.

System scalability requirements are achieved through a modular architecture. An experimental teaching platform supports seamless switching between frameworks such as TensorFlow and PyTorch. In the development of the concrete strength prediction module, students can independently choose the XGBoost algorithm suitable for small sample data or the Transformer architecture for time-series features.

This flexibility brought an unexpected benefit—one team introduced natural language processing technology into the analysis of engineering change orders, developing a contract clause conflict detection tool with an accuracy rate of 82%.

The design of the data security mechanism embodies the concept of defense-in-depth. A bidding simulation system jointly developed by a university and an enterprise adds dynamic access control functionality based on the Grade 3 certification of the Information Security Protection Classification System 2.0. When abnormal login behavior is detected, the system automatically initiates sandbox isolation and injects fake data, effectively preventing a penetration attack targeting the bid evaluation strategy model. The resource update mechanism establishes a "industry trigger-education response" linkage mode. For example, after the release of new quotas, the teaching case library must complete parameter calibration of the supporting algorithm model within 22 working days to ensure that the knowledge iteration rate is synchronized with industry development.

5. Summary

The intelligent transformation of education faces multiple practical challenges. The collaborative dilemma between technical logic and educational laws is highlighted by the erosion of teaching transparency caused by the black-box algorithm. Nearly one-third of learners have difficulty tracing the root cause of intelligent decision-making errors, which forces the teaching system to integrate visual explanation modules and rebuild cognitive trust through decision-making path playback and key variable labeling. The problem of teacher structure fault is more serious. More than 60% of professional teachers are limited by traditional knowledge systems. It is urgent to build a three-track training mechanism that integrates university theoretical instructors, enterprise practice experts, and AI research and development teams. The joint development of enterprise certification projects and teaching agents has become a key fulcrum for capability transition.

Data ethics risks run through the entire teaching process, and the commercial sensitivity of project cost requires the establishment of a full-cycle protection system. From the federal learning to protect the privacy of raw data, to the blockchain technology to track the flow of information, to the timing reset mechanism to avoid residual risks, this layered prevention and control model has successfully blocked multiple potential data leakage incidents in the pilot. It is noteworthy that the compliant use of teaching data and the open demand for knowledge creation form a tension, and how to release data value beyond the safety baseline still needs to be explored in depth.

Research has confirmed that the new cultivation chain driven by AI has shown the power of paradigm innovation. The digital twin environment reconstructs the engineering cognitive dimension, and the intelligent deduction mechanism cultivates dynamic decision-making thinking. This dual transformation resonates with the talent capabilities and the process of industrial intelligence. Future breakthroughs will focus on the creative empowerment of generative technology and the balance of alienation risks, the deep coupling of education platforms and industrial Internet, and the verification of brain cognitive mechanisms on the effectiveness of intelligent teaching. These explorations will promote engineering education from adaptive reform to leading innovation, and provide sustainable talent momentum for the transformation and upgrading of the construction industry.

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