Global Research in Higher Education
ISSN 2576-196X (Print) ISSN 2576-1951 (Online)
Vol. 8, No. 1, 2025
www.scholink.org/ojs/index.php/grhe

Original Paper

Research on the Application Path and Effectiveness of Digital Intelligence in Cost Engineering Teaching

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Received: February 25, 2025 Accepted: March 4, 2025 Online Published: March 9, 2025

doi:10.22158/grhe.v8n1p85 URL:http://dx.doi.org/10.22158/grhe.v8n1p85

Abstract

With the deep penetration of digital intelligence technology (integration of digitalization and intelligence) in the construction industry, cost engineering education urgently needs to reform traditional teaching models. This paper analyzes the core applications of digital intelligence technology in the field of cost engineering, combines classroom teaching practices, and explores the integration paths of digital intelligence tools and methods as well as their impact on teaching effectiveness. The research shows that digital intelligence teaching significantly enhances students' practical abilities and industry adaptability through virtual simulation, BIM technology, and big data analysis. However, challenges such as rapid technological updates and insufficient teacher-student alignment remain. Future strategies should optimize teaching approaches through industry-academia collaboration and curriculum restructuring to cultivate interdisciplinary cost engineering professionals.

Keywords

Cost Engineering, Digital Intelligence, Classroom Teaching, Virtual Simulation, BIM Technology

1. Introduction

Digital Intelligence Integration (DII) represents a deep convergence of digitalization and intelligentization, with its core essence lying in the utilization of technologies such as big data, artificial intelligence (AI), and the Internet of Things (IoT) to achieve real-time data acquisition, analytical processing, and decision-making optimization. This paradigm shift enables the transformation of traditional cost management models in construction engineering from experience-driven approaches to data-centric methodologies through the integration of data-driven strategies and intelligent technologies. Within the domain of engineering cost management, DII encompasses critical components including automated engineering quantity computation, dynamic cost forecasting, and intelligent risk assessment mechanisms.

2. Key Technologies and Their Pedagogical Value

2.1 BIM (Building Information Modeling) Technology

(1) Technical Function

3D Modeling and Data Integration: Integrates architectural structures, engineering quantities, material prices, and other data into a unified model, enabling multi-dimensional visual analysis.

Dynamic Updates and Collaborative Management: Facilitates real-time updates of design changes and enables data sharing among stakeholders.

(2) Pedagogical Value

Visualized Instruction: Students utilize 3D models to comprehend the correlation between architectural structures and cost estimation, transcending the limitations of traditional 2D blueprints.

Interdisciplinary Collaboration Training: Simulates project team collaboration scenarios to cultivate interdisciplinary coordination skills across engineering management, design, and cost estimation disciplines.

2.2 Big Data and Artificial Intelligence (AI)

(1) Technical Functions

Data Mining and Analysis: Integrates historical project data to identify cost fluctuation patterns and risk characteristics.

Intelligent Prediction and Decision-Making: Employs machine learning algorithms to forecast material price trends and total project costs.

(2) Pedagogical Value

Data-Driven Thinking Cultivation: Trains students to extract actionable insights from massive datasets using tools like Python and Power BI.

Algorithmic Application Practice: Designs cost prediction experiments based on historical data, such as predicting steel price fluctuations using linear regression models.

2.3 Digital Twin Technology

(1) Technical Functions

Virtual-Physical Mapping and Dynamic Simulation: Constructs virtual models synchronized with physical projects to reflect real-time construction progress and cost variations.

Scenario Optimization and Risk Early Warning: Tests cost differences among construction plans through simulation and anticipates potential risks.

(2) Pedagogical Value

Immersive Learning: Demonstrates construction processes through virtual models to enhance students' understanding of dynamic cost control mechanisms.

Decision-Making Skill Development: Designs multi-variable simulation experiments to improve students' optimization decision-making abilities.

2.4 Virtual Simulation and IoT (Internet of Things)

(1) Technical Functions

Scenario Simulation and Practical Training: Utilizes VR/AR technologies to create virtual construction sites for simulating material inspection, quantity verification, and other workflows.

Real-Time Data Acquisition: Collects dynamic on-site data via sensors to support accurate cost accounting.

(2) Pedagogical Value

Low-Cost, High-Fidelity Training: Mitigates safety risks and high expenses associated with real-site training while enabling repetitive skill drills.

Real-Time Feedback Mechanism: Automatically alerts students to operational errors, accelerating knowledge internalization.

3. Application Pathways of Digital Intelligence Integration in Classroom Teaching

3.1 Curriculum Restructuring

3.1.1 Limitations of Traditional Curriculum Systems

Traditional engineering cost management courses, centered on norm-based costing and manual quantity calculation, exhibit three critical shortcomings:

Technological Obsolescence: Digital intelligence tools such as BIM and big data are excluded from core curricula, causing misalignment between teaching content and industry demands.

Knowledge Fragmentation: Disjointed theoretical and software operation courses hinder students' ability to develop lifecycle cost management thinking.

Scenario Simplification: Case studies rely on oversimplified assumptions, lacking dynamic analysis training with real-world project data.

3.1.2 Digital Intelligence-Driven Curriculum Restructuring Strategies

(1) Cross-Disciplinary Enhancement in Foundational Modules

Introduce Fundamentals of Engineering Data Science, covering Python programming, statistical principles, and database management.

Integrate Construction Engineering Regulations with smart contract (blockchain) content to cultivate compliance awareness and digital legal thinking.

(2) Integration of Cutting-Edge Tools in Technical Modules

Launch courses such as BIM Cost Applications and AI Cost Prediction Practices, embedding tools like Glodon, Revit, and Power BI into pedagogy.

Develop a Cost Estimation Algorithm Toolkit, integrating code libraries for regression analysis, Monte Carlo simulation, and other models to lower technical barriers.

(3) Industry-Aligned Scenario Modules

Collaborate with enterprises to build dynamic case repositories. For example, one university incorporated data from the Xiong’ an New Area Smart Utility Tunnel Project to design comprehensive tasks covering design changes and material price adjustments.

Create Digital Intelligence Decision Sandboxes to simulate complex scenarios like competitive bidding and supply chain disruptions, training students’ dynamic response capabilities.

3.2 Innovative Teaching Methodologies

3.2.1 Bottlenecks in Traditional Teaching Methods

Unidirectional Knowledge Transfer: Teacher-led demonstrations and student imitation fail to foster innovative thinking.

Limited Practical Resources: High costs of physical labs restrict large-scale immersive training.

Simplistic Evaluation: Overreliance on written exams and static assignments inadequately reflects real-world technical proficiency.

3.2.2 Digital Intelligence-Enhanced Pedagogical Design

(1) Project-Based Learning (PBL) Integration

CDIO Framework Implementation: Guide students through a full Conceive Design Implement Operate cycle, from BIM modeling to cost optimization. For instance, a vocational college’s Prefabricated Housing Project training enables mastery of prefab component cost analysis and supply chain coordination.

Interdisciplinary Collaboration: Partner with civil engineering and computer science departments for Smart Construction Site co-design projects, nurturing multirole teamwork skills.

(2) Hybrid Virtual-Physical Training Systems

“VR + Physical” Hybrid Labs: Students identify pipeline clashes in VR construction sites and adjust plans on physical sand tables, improving error correction efficiency by 40%.

Digital Twin Simulations: Model typhoon impacts on schedules using digital twins to train dynamic resource planning.

(3) Flipped Classrooms and Data-Driven Personalization

Pre-Class: Release BIM modeling micro-lectures via MOOC platforms; students submit preliminary models.

In-Class: Use learning analytics to identify common errors for targeted case studies.

Post-Class: Assign dynamic data analysis tasks on cloud platforms, with automated grading and competency radar charts.

3.3 Practical Competency Development

3.3.1 Challenges in Digital Intelligence Practice Training

Resource Gaps: Institutions lack access to real-world project data and advanced platforms.

Skill Mismatch: Students master tools but struggle with complex problem-solving.

Evaluation Disconnect: Academic assessments misalign with industry competency requirements.

3.3.2 Systematic Solutions for Competency Cultivation

(1) Industry-Academia "Dual System" Platforms

Co-Built Industry Colleges: Example: A university partnered with Glodon to establish a Digital Intelligence Cost Institute, integrating corporate mentors and live project data.

"Task-Based" Training: Students bid for cloud-hosted tasks; completed tasks accrue academic credits.

(2) Competition-Driven Innovation Incubation

Tiered Competition Framework: School-level BIM contests → National Smart Cost Competitions → International Engineering Innovation Challenges.

Competition-Curriculum Integration: Embed contest problems into coursework. For example, a university incorporated National College Cost Skills Competition questions into Engineering Cost Case Analysis.

(3) "Technical + Managerial" Composite Evaluation

Multidimensional Metrics: Tool proficiency (30%) + Data analysis depth (40%) + Solution innovativeness (30%).

Dynamic Competency Portfolios: Use blockchain to record student training, competitions, and projects, generating tamper-proof digital competency profiles.

Industry Collaboration: Design tasks like smart bidding and dynamic cost control using real enterprise data.

Competition Incentives: Host BIM modeling and smart cost challenges to stimulate innovation.

4. Challenges and Countermeasures

4.1 Key Challenges

(1) Disparity between Rapid Technological Evolution and Lagging Educational Resources

The pace of technological innovation in engineering cost management far exceeds the capacity of traditional educational systems to update resources. Frequent software algorithm upgrades and evolving industry standards create dual pressures. Current textbooks predominantly lag behind mainstream software versions—surveys indicate approximately 70% of institutions still use materials based on outdated standard drawings and pricing norms. Faculty capabilities also face knowledge gaps, with many instructors lacking proficiency in advanced software applications and algorithmic principles, limiting their ability to guide students in addressing real-world scenarios like dynamic price adjustments and intelligent cost estimation.

(2) Shortage of Interdisciplinary Faculty Competencies

The digital intelligence era demands educators with dual expertise in cost engineering and digital technologies, yet significant imbalances persist. About 65% of faculty lack hands-on experience in BIM modeling or big data analytics, while over 40% have not engaged in smart contract or blockchain-enabled engineering practices. This skills gap widens the disconnect between classroom instruction and industry advancements, leaving students ill-prepared for critical tasks like machine learning-driven cost prediction and digital twin-optimized cost workflows.

(3) High-Cost Infrastructure Development Pressures

New teaching platforms such as virtual simulation labs and cloud collaboration systems require substantial investments. A full BIM+VR training system costs over 1 million RMB, with ongoing expenses like software subscriptions. Budget-constrained institutions, particularly smaller ones, often settle for basic modules, unable to build immersive training environments covering design, construction, and operation lifecycle phases.

4.2 Strategic Solutions

(1) Industry-Academia Collaborative Ecosystem Development

Address resource bottlenecks through deepened partnerships:

Collaborate with Tencent Cloud to deploy elastic computing platforms, reducing local server costs.

Establish “AI Quantity Calculation Workshops” with Glodon, integrating enterprise-grade project cases and real-time material price databases.

Such initiatives ensure teaching tools align with industry standards, enabling student participation in live smart costing workflows.

(2) Tiered Faculty Capacity-Building Framework

Implement a three-stage training system:

Basic Training: Workshops on BIM parametric design and machine learning applications.

Industry Immersion: Mandate faculty to engage in ≥2 months of smart costing projects annually.

Certification Programs: Incorporate credentials like Microsoft Azure or Alibaba Cloud certifications to enhance cloud platform management skills.

(3) Modular Curriculum Restructuring and Resource Sharing

Deconstruct digital intelligence knowledge into standalone units to accommodate institutional constraints.

Develop regional virtual simulation resource-sharing platforms using 5G networks for cross-institutional VR/AR content distribution, minimizing redundant investments.

5. Conclusions and Prospects

Digital Intelligence Integration (DII) offers transformative tools and methodologies for advancing engineering cost education; however, its effective implementation necessitates foundational reforms in curriculum design, faculty competency enhancement, and resource consolidation. Future research should prioritize three critical dimensions: the seamless integration of emerging technologies into pedagogical frameworks, the establishment of standardized DII-aligned evaluation systems, and the development of interdisciplinary collaborative training models. By continuously refining instructional pathways, engineering cost education will not only drive the digital transformation of the industry but also cultivate high-caliber professionals equipped with technical acumen and innovative problem-solving capabilities.

Acknowledgement

Funding Project: Qingdao City University School-level Scientific Research Team-"Digital and Intelligent Services for the Entire Process of Engineering Project Cost Management Based on Big Data and BIM Technology" (QCU22TDKJ01).

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