

Reforming the "Construction Project Management" Course for Digital Architecture

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Abstract: The traditional "Construction Project Management" course still suffers from disconnected content, insufficient practical opportunities, and a lack of personalized guidance in practical training, BIM skills application, and student comprehensive development. This paper explores a course reform plan for digital architecture. By introducing BIM virtual simulation, modular task design, and generative teaching resources, it achieves a deep integration of theory and practice. This study, based on a KT modular teaching mechanism, divides the course content into four modules: theoretical knowledge mapping, BIM practical skills training, ideological and political education, and spiral evaluation. A virtual simulation platform is used to conduct engineering construction simulations. Learning analytics data (activity and number of retries) are combined to monitor student learning progress and dynamically adjust the teaching plan. The experiment compared the experimental and control groups to evaluate the effectiveness of the teaching method in improving students' practical skills, self-efficacy, and overall abilities. The teaching method had a significant positive impact on the level of practical skills ($\beta=1.12$, $SE=0.42$, $z=2.67$, $p=0.008$, $OR=3.06$, 95% CI [1.33, 7.03]), indicating that students in the experimental group were more likely to achieve higher levels than those in the control group. Improved learning motivation also significantly promoted improvements in practical skills ($\beta=0.85$, $SE=0.30$, $z=2.83$, $p=0.005$, $OR=2.34$, 95% CI [1.29, 4.24]).

1. Introduction

As the construction industry enters a phase of digital and intelligent transformation, traditional project management models are increasingly unable to meet the efficiency, quality, and collaboration requirements of the new era of engineering construction. Driven by the concept of "digital architecture," emerging technologies such as Building Information Modeling (BIM), the Internet of Things, and artificial intelligence are being widely applied to the full lifecycle management of projects. This places higher demands on construction project management courses in both vocational and undergraduate institutions. However, existing curricula still suffer from a heavy focus on theoretical indoctrination, weak practical components, insufficient attention to detail, and a single-minded process evaluation. This leads to significant shortcomings in students' practical project execution and the development of comprehensive skills.

To address these issues, curriculum reform urgently needs to be deeply integrated with the development of digital architecture. In recent years, the development of technologies such as BIM virtual simulation and learning analytics has opened up new possibilities for educational reform. On the one hand, BIM technology can provide students with a realistic project management environment, helping them perform tasks and control details in a virtual space. On the other hand, the collection and analysis of process data can provide a basis for teachers to dynamically adjust their teaching, thereby achieving precise and personalized teaching.

Based on this, this paper, focusing on the "Construction Project Management" course, proposes a teaching system centered on "BIM virtual simulation + KT modular teaching." It incorporates four modules: knowledge, skills, ideological and political education, and evaluation, forming a three-dimensional collaborative development path: "knowledge-ability-literacy." In this empirical study, by comparing the experimental and control groups, and combining ANCOVA analysis, ordered logit regression, and mediation effect testing, this paper systematically evaluates the impact of the curriculum reform on students' knowledge acquisition, practical skills, comprehensive abilities, and self-efficacy, revealing the mechanisms and practical value of digital curriculum reform.

2. Related Works

In order to further clarify the research basis and academic background of the construction project management curriculum reform, it is necessary to sort out the relevant research progress in architectural education, project management and digital technology integration around the world. Maqbool and Jowett used a snowball sampling method to conduct an online closed-ended questionnaire survey of architectural and engineering professionals in the UK construction industry. They found that most participants agreed to encourage sustainable building practices, but were generally unsure of what they could do [1]. Posillico et al. proposed a conceptual model for construction management curriculum development. The results showed that the existing body of knowledge lacks a unified research core on construction management curriculum development. Instead, customized curriculum development research dominates in isolated and uncommunicative settings [2]. Almashhadani et al. explored how educational factors affect construction project planning, budgeting, quality control, and risk management. They pointed out that construction managers can succeed in the ever-changing construction industry through continuing education and professional development [3]. Aliu and Aigbavboa used the text mining tool VOSviewer to analyze the bibliometric relationships of research within the discipline of built environment. The results were sorted by cluster analysis. The results showed that the focus was on student-centered learning, building information modeling, sustainability, active learning, virtual reality and project management [4]. Stanitsas and Kirytopoulos used a questionnaire survey to investigate the opinions of stakeholders in the construction industry on the use of sustainable project management indicators when seeking project sustainability attributes. The results showed that using the relative importance index method, environmental indicators were identified as the most important indicators [5]. Abdulhadi et al. studied the relationship between internal control and project management in small and medium-sized enterprises in the Iraqi construction industry through a questionnaire survey. Model measurement and structural equation model testing showed that internal control has a positive impact on the four main components of project management in SMEs in the Iraqi construction industry[6]. Zwikael et al. identified project management concepts that key stakeholders should understand to promote effective communication. The study identified five threshold concepts of project management that are difficult for project stakeholders to understand: (1) project benefits, (2) iron triangle, (3) critical path, (4) uncertainty, and (5) project leadership[7]. Orieno et al. identified three core dimensions of project management sustainability: environmental responsibility, social equity, and economic feasibility.

They pointed out that life cycle assessment, stakeholder engagement strategy and sustainability balanced scorecard can be used to support the development of sustainable project management tools and frameworks [8]. Seyman Guray used a digital model for building construction courses in architectural education. The model is based on the integration of BIM (Building Information Modeling) and AR (Augmented Reality) and is applied to the third-year "Building Construction Project" course. Each student designed a residential building and drew construction drawings based on the model accordingly. According to the survey results, the use of BIM-based augmented reality digital modeling is considered beneficial [9]. Olbina and Glick explored the combination of VR and AR in the construction of physical structures. Students believed that VR, AR and hands-on activities helped to improve their imagination of building structures [10]. Liang analyzed the research on BIM technology in the teaching of architectural technology courses. BIM technology can simulate the construction process, which is conducive to concretizing abstract knowledge and making it easier for students to understand [11]. Although existing research has achieved certain results in sustainability, digital technology and curriculum development, there are still limitations in the overall research, such as scattered research, lack of a unified framework and insufficient practical verification.

3. Methods

3.1 Establishing a KT Modular Teaching Mechanism

This study is mainly aimed at students in local applied universities and aims to improve the quality of teaching, and incorporating new technologies, techniques, and standards in the context of digital architecture, the paper has established a "KTIE" teaching mechanism for the "Construction Project Management" course (i.e., "Theoretical Knowledge Graph," "Architectural BIM Practical Skills Training," "Ideological Education," and "Evaluation Mechanism").

In building a knowledge system, the paper relies on knowledge graphs to lay a solid foundation. A knowledge graph is a structured, semantically based visual database that can organize and systematize scattered engineering management knowledge, forming a visual, dynamic knowledge network. "Construction Project Management" covers multiple aspects, including quality, schedule, cost, safety, contracts, information management, and organizational coordination. Students often find the knowledge points scattered when studying. Knowledge graphs can strengthen the logical connections between knowledge points and help students build a complete cognitive system. Combined with artificial intelligence technology, it can also implement intelligent retrieval and question-answering, building an interactive learning platform for digital construction to support students' independent learning and knowledge expansion.

3.2 Cultivating Students' Practical Skills with Digital Tools

Digital construction emphasizes information-based and intelligent management throughout the entire process, so engineering management software should be fully utilized in teaching.

Project management software, utilizing tools such as Microsoft Project, Primavera P6, and Synchro, allows students to assume the roles of owner, contractor, and supervisor in a virtual construction environment, conducting dynamic cost, schedule, and quality management training.

Bill of Materials and cost management software, utilizing software such as "Bill Star" and Glodon, provides training in bid preparation, budgeting, settlement, and review. Students work as bidding teams to complete commercial bid quotations and experience the actual project bidding process through bidding simulations.

Through practical training with these digital tools, students can master project management logic and operational skills in digital construction scenarios, enhancing their ability to solve practical

engineering problems.

3.3 Case-Based Teaching and Virtual Simulation to Stimulate Student Learning Enthusiasm

The traditional "chalk and lesson plan" approach is insufficient to meet the teaching needs of digital architecture. A case-based teaching model based on BIM, CIM, and virtual simulation should be introduced:

Utilizing technologies such as 3D visualization, construction simulation, and virtual reality (VR/AR) to dynamically present scenarios such as building structure, construction organization, and mechanical layout;

Through the school's online platform, we introduced project management software such as Glodon's electronic sandbox and Magnum schedule planning software to provide students with simulation exercises of the entire project process;

Using virtual simulation cases (such as those for large-scale public buildings and transportation infrastructure projects), students can enhance their intuitive understanding and engagement with complex project management issues.

In terms of assessment, a diverse approach can be adopted, including open-book exams, course papers, case studies, classroom presentations, group discussions, and individual research. This can test students' "four consciousnesses" and "six abilities," thereby organically integrating theory with practice.

3.4 Improve the Syllabus and Expand Experimental Content

To adapt to the development of digital architecture, virtual simulation experiments should be added to the curriculum to highlight students' core role and practical skills.

For example, in the teaching of glodon building construction and progress management, a virtual simulation experiment platform can be introduced. Students need to complete the whole process of "making construction plans - optimizing schedules - simulating construction processes - inspection and correction" to realize project drills in a digital twin environment. Through the task-driven teaching method of "teacher guidance + student autonomy", students can make progress plans, optimize construction plans, inspect construction logic, and continuously adjust and improve in a virtual scene. This immersive experience not only enhances students' practical ability, but also cultivates their creative thinking and data-based decision-making ability.

3.5 Course Content Design

In terms of course content, the core tool of digital construction - BIM5D technology should be the focus to carry out the whole process engineering management teaching.

(1) Building Information Model Management System Architecture

This course introduces common operations of BIM management systems and related software (Revit, Navisworks, Glodon, etc.), emphasizing data import and export and multi-platform collaboration.

(2) Application of BIM5D Technology

Through digital collaborative management scenarios for quality, safety, and cost, students are guided through full-process training, such as construction material procurement, funding approval, quota-based material collection, subcontract management, schedule control, and cost control. Combining 3D sectioning, reinforcement visualization, path simulation, and free roaming functions, students are helped to intuitively understand the dynamic project management process.

Focusing on the work of supervisory engineers and estimators, training was conducted on progress

and cost control, network diagram design, and 4D building simulation. The BIM5D platform not only provides data support for decision-making by owners and investors, but also serves as a basis for construction cost and schedule adjustments. Through centralized collaboration among owners, contractors, and supervisors, planning, resource allocation, project dashboards, and streamlined construction models were optimized, ultimately achieving digital management and control throughout the entire process.

4. Results and Discussion

4.1 Experimental Design

Type: Class-based quasi-experimental/cluster randomized controlled trial (randomization if conditions permit), pretest-posttest-delayed posttest design.

Sample: 4 parallel classes, $N \approx 30$ students; each class divided into 3–5 groups.

Period: 8 weeks (including two interim assessments and one delayed posttest; see timeline).

Groupings:

Experimental Group: Implemented KTIE (knowledge graph + BIM/CIM/virtual simulation + task-driven + spiral evaluation).

Control Group: Continued conventional lectures + standard practical training (no systematic knowledge graph, no BIM5D integration, no virtual simulation closed loop).

4.2 Tasks and Outputs

Task A: Glodon Building Project Schedule-Cost Collaboration (Core Project)

Input: Given WBS, key process capacity, resource unit price, material arrival cadence, and risk scenario (rainy season/mechanical failure). Tools: Glodon electronic sand table, Glodon schedule planning software.

Requirements:

Students are required to complete the following tasks: first, establish a work breakdown structure (WBS) and a dual-coded network diagram; second, generate a baseline progress and cost curve (S-curve); then, conduct two rounds of optimization, including resource balancing, work time rhythm, and process organization; then, use 4D simulation to demonstrate the difference between the baseline results and the optimized results; finally, write a decision report, including risk scenario simulation and response strategies.

Task B: Construction Organization and Safety Planning for a Public Building

Input: BIM model (including structural/mechanical/electrical), site layout constraints (roads, cranes, temporary facilities).

Tools: Revit + Navisworks (collision checking, path simulation), Project/P6 (schedule).

4.3 Timeline (8 weeks)

W0: Pre-test (knowledge/motivation/self-efficacy/moral education scenario); baseline test for tool training.

W1: Progression of Task B (Phase Assessment 1, W1).

W2–W6: Task A Progression (Phase 2 Assessment, W4; Final Review, W6).

W8: Delayed Posttest (Knowledge Test + Key Skills Test + Questionnaire).

4.4 Data Collection and Quality Control

Table 1 ANCOVA Analysis Results (Knowledge Posttest as the Dependent Variable, Knowledge Pretest as the Covariate)

Source	S	df	MS	F	p	Partial η^2
Group	210.35	1	210.35	18.25	0.002	0.695
Pre-test (Covariate)	85.72	1	85.72	7.43	0.027	0.452
Error	80.12	7	11.45	—	—	—
Total	376.19	9	—	—	—	—

To assess the impact of the curriculum reform on students' knowledge acquisition in Table 1, this paper conducted an ANCOVA analysis using posttest scores as the dependent variable and pretest scores as the covariate. The results showed a significant effect of group on posttest scores ($F=18.25$, $p=0.002$, partial $\eta^2=0.695$), indicating that students in the experimental group achieved significantly higher knowledge acquisition than those in the control group under the curriculum reform intervention. Furthermore, pretest scores, as a covariate, also had a significant effect on posttest scores ($F=7.43$, $p=0.027$, partial $\eta^2=0.452$), indicating that students' foundational knowledge level influenced the improvement in knowledge acquisition to a certain extent. The sum of squared errors was 80.12, with 7 degrees of freedom (df) and a total sum of squares of 376.19.

When researchers evaluate students' practical and comprehensive abilities, if the rating scale is ordinal data, they should use ordered logit regression analysis or convert it into numerical scores for statistical processing.

Dependent Variable: Practical Ability Level (1–4)
Independent Variable:
Teaching Method (Experimental = 1, Control = 0)
Learning Motivation Improvement
Baseline Performance (Pre-test)

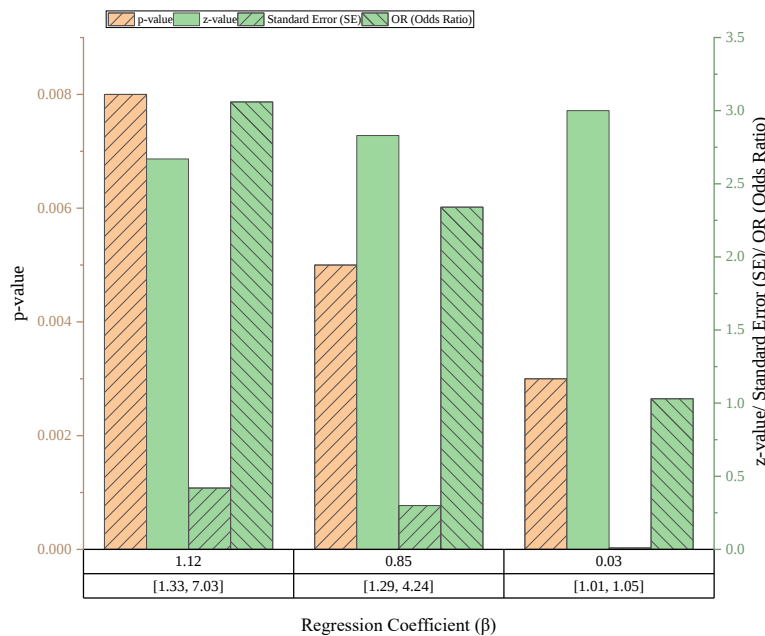


Figure 1 Ordered Logit Regression Table

To further explore the impact of teaching reform on students' practical skills in Figure 1, this paper employed an ordered logit regression model with practical skills level (1–4) as the dependent variable and independent variables including teaching method (experimental group = 1, control group = 0),

learning motivation improvement, and baseline performance (pretest). The analysis results showed that teaching methods had a significant positive impact on practical ability levels ($\beta=1.12$, $SE=0.42$, $z=2.67$, $p=0.008$, $OR=3.06$, 95% CI [1.33, 7.03]), indicating that students in the experimental group were more likely to achieve higher levels than those in the control group. Increased learning motivation also significantly promoted improvements in practical ability ($\beta=0.85$, $SE=0.30$, $z=2.83$, $p=0.005$, $OR=2.34$, 95% CI [1.29, 4.24]). Furthermore, although the coefficient for basic performance (pretest) was small, it still had a statistically significant impact on level improvement ($\beta=0.03$, $SE=0.01$, $z=3.00$, $p=0.003$, $OR=1.03$, 95% CI [1.01, 1.05]), indicating that students' basic level also influenced their practical ability performance.

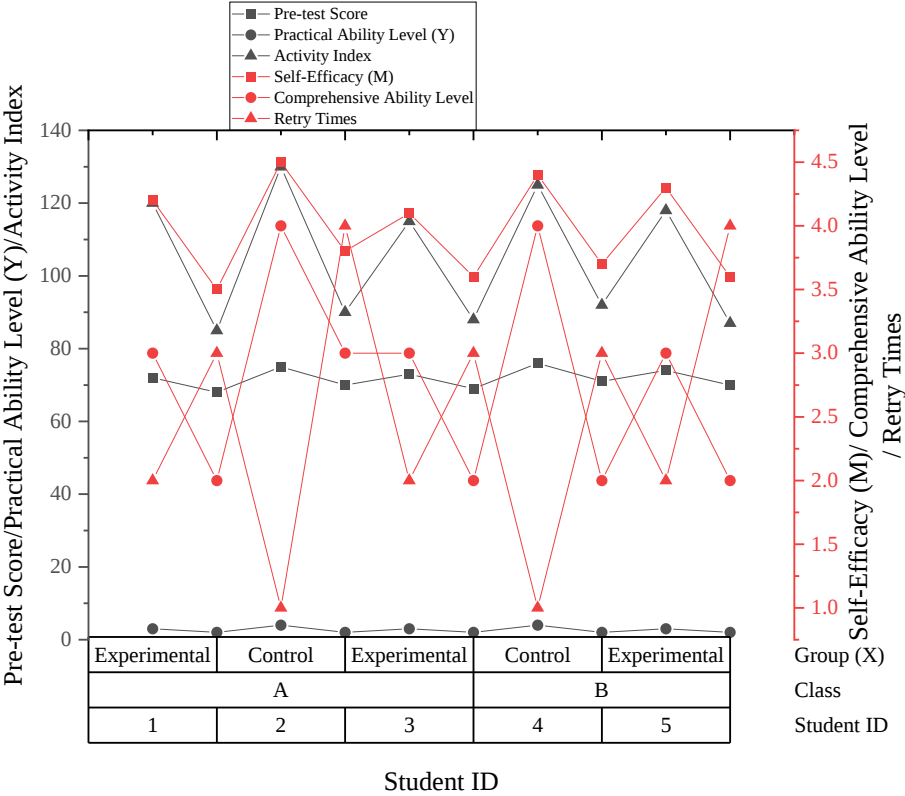


Figure 2 Practical and Comprehensive Ability Indicators for Students in the Experimental and Control Groups

To visually demonstrate the impact of the teaching reform on students' practical and comprehensive abilities, this paper compiled key indicator data for the experimental and control groups (Figure 2). The figure shows that the experimental group's practical ability level (Y) and comprehensive ability level were generally higher than those of the control group. For example, the experimental group's practical ability level was concentrated between 3 and 4, while the control group's level was primarily 2. In terms of self-efficacy (M), the experimental group showed higher average scores than the control group, indicating that the teaching reform had a positive impact on students' confidence and skill acquisition. Process data indicators also showed that students in the experimental group demonstrated greater engagement and more rational attempts in terms of activity and number of retries: the average activity index was higher, while the number of retries was lower, indicating that students were able to complete tasks more effectively. Overall, despite having similar knowledge bases on the pretest, students in the experimental group gained higher practical and comprehensive abilities through the curriculum reform, validating the effectiveness of the teaching plan in improving students' skills, grasp of details, and learning motivation.

Hypothesis Testing:

Independent Variable X: Group (Experimental Group = 1, Control Group = 0)

Mediating Variable M: Self-Efficacy

Dependent Variable Y: Practical Ability Level

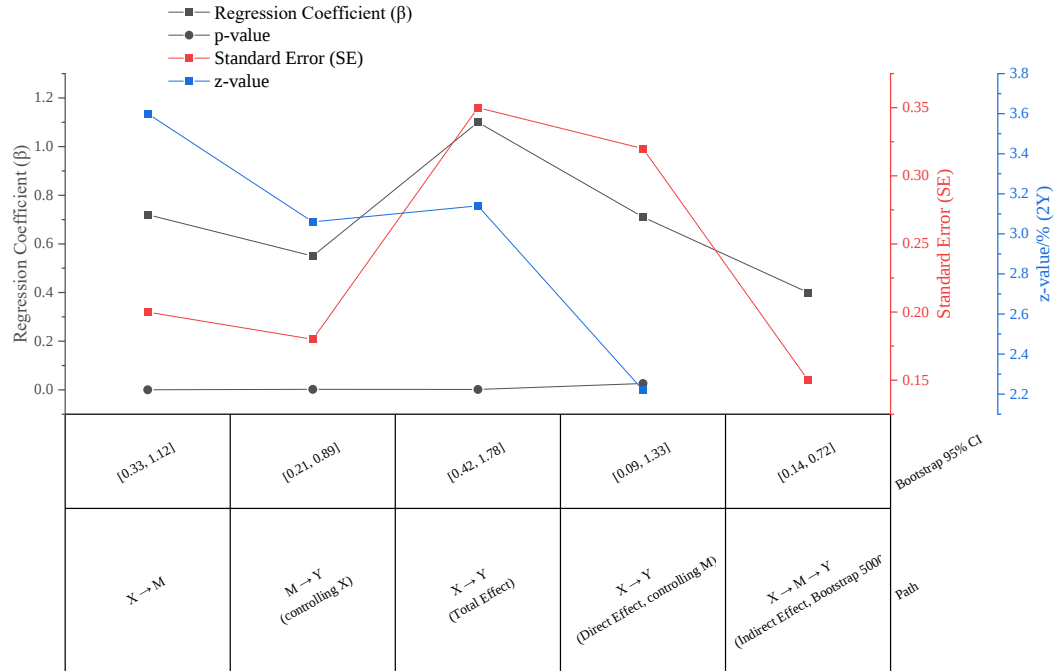


Figure 3 Mediation Analysis (Bootstrap 5,000 Repetitions) Output

To verify the mediating role of self-efficacy (M) in the effect of group (X) on practical ability (Y) in Figure 3, this study conducted a mediation analysis using a bootstrap method (5,000 replicates). The results showed that group had a significant positive effect on self-efficacy ($\beta=0.72$, $SE=0.20$, $z=3.60$, $p=0.0003$, 95% CI [0.33, 1.12]), indicating that students in the experimental group had significantly higher self-efficacy than those in the control group. Even after controlling for group, self-efficacy still had a significant positive effect on practical ability ($\beta=0.55$, $SE=0.18$, $z=3.06$, $p=0.002$, 95% CI [0.21, 0.89]), indicating that self-efficacy can effectively promote the improvement of practical ability. The total effect of group on practical ability was significant ($\beta=1.10$, $SE=0.35$, $z=3.14$, $p=0.0017$). Even after controlling for self-efficacy, the direct effect remained significant ($\beta=0.71$, $SE=0.32$, $z=2.22$, $p=0.026$). The indirect effect was 0.40, with a 95% CI of [0.14, 0.72], indicating a significant and partial mediation effect.

5. Conclusions

This paper examines the "Construction Project Management" Course Teaching Reform for Digital Architecture. To address the disconnect between theory and practice, insufficient process evaluation, and limited student development in traditional courses, a curriculum reform proposal centered on BIM virtual simulation and KT modular teaching is proposed. By constructing four modules—knowledge, skills, ideological and political education, and evaluation—and introducing learning analytics indicators to monitor the learning process, the curriculum achieves visualization and personalization. Experimental results show that the reformed curriculum significantly improves students' knowledge acquisition, practical skills, and overall literacy. ANCOVA analysis confirms the superiority of students in the reform group on the knowledge posttest. Ordered logit regression and mediation effect tests further reveal the interaction between teaching methods, self-efficacy, and

practical skills. Both experimental data and process indicators support the effectiveness of the teaching reform. The sample size is relatively limited, and the research results still need to be further verified in a wider range of applications. Future research can be further expanded by expanding the sample size, extending the inspection period, and enriching the process evaluation dimensions, so as to promote the continuous optimization and in-depth development of the construction project management curriculum reform in the context of digital construction.

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