Development of a BIM-Based Virtual Simulation Training Platform for Construction Management Education: Postprint

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Abstract

Promoting practical teaching reform and enhancing students' engineering practice capabilities and comprehensive professional qualities constitute important initiatives for comprehensively implementing national medium- and long-term education reforms, and serve as crucial means for cultivating interdisciplinary, application-oriented, and innovative entrepreneurial talents. However, current practical teaching exhibits issues such as insufficient depth and weak interconnectivity. Furthermore, the widely adopted approach of conducting internships and practical training at construction enterprises or engineering project sites entails safety risks and is subject to temporal and spatial constraints. This paper first summarizes the current state of BIM application in the educational domain both domestically and internationally, then proposes the construction objectives for a BIM virtual simulation training platform, designs an overall system architecture diagram that divides the platform into sub-platforms including architectural structure design training, construction virtual simulation training, BIM engineering cost estimation training, and BIM integrated project management training, and finally presents the schematic principles of the cloud architecture for the training platform along with a list of the main hardware and software components, providing a reference for peers to establish similar training platforms.

Full Text

Preamble

Research on the Construction of BIM Virtual Simulation Training Platforms for Construction Management Education

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Abstract: Implementing practical teaching reforms and enhancing students' engineering practice capabilities and professional comprehensive qualities are crucial measures for fully executing national medium- and long-term education reform initiatives, and represent an important approach to cultivating interdisciplinary, application-oriented, innovative, and entrepreneurial talents. However, current practical teaching suffers from insufficient depth and weak interconnectedness. The widely adopted method of sending students to construction enterprises or project sites for internships presents safety risks and is constrained by time and space limitations. This paper first summarizes the current state of BIM application in education both domestically and internationally, then proposes construction objectives for a BIM virtual simulation training platform, designs an overall system architecture, and divides the platform into sub-platforms for building structure design training, construction virtual simulation training, BIM engineering cost training, and BIM integrated project management training. Finally, the paper presents the cloud architecture principles of the training platform and lists the main hardware and software components to provide reference for peer institutions establishing similar training platforms.

Keywords: BIM; Training Platform; Construction Management; Virtual Simulation

1 Introduction

The construction industry serves as a pillar industry of China' s national economy, creating strong demand for civil engineering and construction management professionals. Construction management is a highly comprehensive and practice-oriented discipline, with over 400 Chinese higher education institutions offering construction management programs as of 2017. The *Undergraduate Guiding Professional Standards for Construction Management in Higher Education Institutions* imposes rigorous requirements on students' quality structure, capability structure, and knowledge structure. Accordingly, curricula are organized around four knowledge systems and five knowledge domains, comprising more than a dozen specialized foundation and direction courses. However, for engineering management students lacking practical experience, classroom instruction alone enables them to acquire isolated knowledge points but makes it difficult to form a comprehensive professional knowledge system. Consequently, practical teaching holds a pivotal position in this discipline.

Promoting practical teaching reform and enhancing students' engineering practice capabilities and professional comprehensive qualities are important measures for fully implementing the *National Medium- and Long-Term Education Reform and Development Plan Outline (2010-2020)*, and represent critical means for cultivating interdisciplinary, application-oriented, innovative, and

entrepreneurial talents. Nevertheless, current practical teaching exhibits insufficient depth and weak interconnectedness. The prevalent approach of sending students to construction enterprises or project sites for internships and practical training also entails safety risks and is limited by time and space constraints. In 2013, based on the *Ten-Year Development Plan for Educational Informatization (2011-2020)*, the Ministry of Education decided to launch the construction of national-level virtual simulation experimental teaching centers [1]. The initiative aims to encourage universities to employ multimedia virtual reality technology and numerical simulation technology to construct highly realistic virtual experimental environments and objects, while conducting reform research and practical exploration in teaching methods and experimental approaches, thereby ensuring that practical training keeps pace with technological developments [2].

Building Information Modeling (BIM) represents an innovative approach to building design, construction, and management. Based on shared information models, BIM enables collaborative management among all project participants throughout the entire lifecycle of engineering projects—from decision-making and design to construction, operation, and maintenance—thereby eliminating information silos. Exploring how to utilize BIM virtual simulation training platforms to cultivate students' comprehensive professional abilities to analyze, research, and solve practical engineering management problems holds both theoretical value and significant practical importance. This paper first summarizes the current state of BIM application in education both domestically and internationally, then proposes construction objectives and specific content for a BIM virtual simulation training platform, and finally presents a cloud architecture diagram of the platform while enumerating the main hardware and software components to provide reference for peer institutions establishing similar platforms.

2.1 BIM Application Status in Foreign Education

BIM is one of the most promising technologies in the construction industry' s recent development. In the United States, BIM adoption rates in the construction sector increased from 28% in 2007 to 71% in 2012 [3]. To meet the construction industry' s demand for BIM talent, numerous American universities have integrated BIM technology into teaching reforms. The primary curriculum models for BIM courses in architecture or construction management programs include: single-course models, interactive teaching models, multi-course integrated models, and capstone design models, covering architectural design courses, structural design courses, specialized courses, and construction management courses. The UK government mandated that all public building projects must adopt BIM design processes starting in 2016. To satisfy industry demand for BIM professionals, higher education institutions such as the University of Westminster, University of the West of England, and University of South Wales have all introduced relevant BIM courses [5].

In Australia, some Technical and Further Education (TAFE) institutions offer

BIM-related courses, which generally focus on specialized BIM software usage training while rarely considering BIM management and work processes in collaborative environments [6]. In Pakistan, only 41% of architecture universities offer or are exploring BIM courses, and it is estimated to take five years to integrate BIM into existing curricula, with the greatest challenge being the lack of well-trained instructors [7].

2.2 BIM Application Status in Domestic Education

Several domestic universities have also conducted BIM-related research. For instance, in 2005, the School of Architecture at South China University of Technology jointly established a Building Lifecycle Management BIM Laboratory with Autodesk [8]. In 2010, Tsinghua University proposed a Chinese building information modeling standard framework by referencing NBIMS and conducting research; in 2013, Tsinghua University and Glodon Company jointly established a BIM Research Center. The BIM Engineering Center at Huazhong University of Science and Technology was established in 2011. Only a few domestic universities have offered BIM software courses at the undergraduate level, such as Tsinghua University, Tongji University, Tianjin University, and Huazhong University of Science and Technology. Additionally, a small number of universities offer BIM courses as electives, including Shandong Jianzhu University, Xi' an University of Architecture and Technology, and Shenyang Jianzhu University.

Construction-related vocational colleges (e.g., Sichuan College of Architectural Technology, Zhejiang Guangsha College of Applied Construction Technology) have proposed strategies for BIM talent cultivation, including reforms in professional course content, BIM-based virtual simulation teaching, and innovative school-enterprise cooperation, while exploring training models for BIM technical personnel [9]. Some university teachers have applied BIM technology to courses such as *Architectural Drawing and Construction* [10], *Steel Structures* [11], and *Engineering Project Management* [12]. China University of Mining and Technology has applied BIM technology to innovation training programs for civil engineering undergraduates, building structure competitions, and capstone design projects [13].

Tu Jinsong from West Anhui University proposed constructing a comprehensive training platform for civil engineering specialties based on BIM technology, covering architectural design, structural design, equipment design, quantity surveying, and construction simulation [14]. Chen Liping from Nanchang Institute of Technology briefly discussed the significance of BIM technology in construction management teaching and the requirements for constructing a BIM-based engineering management teaching and training platform, but did not address specific construction methods [15]. Zhang JinYu, in discussing reforms to the BIM talent training model for engineering cost majors in vocational colleges, also proposed ideas for establishing BIM technology training bases and approaches to enhancing students' BIM skills through skill competitions [16]. Bai Quan et al. summarized the research and practice of BIM teaching reforms for civil en-

gineering majors at Shenyang University of Technology, focusing on BIM-based curriculum system design and various teaching reform practices [17].

In summary, BIM technology is being increasingly applied in education both domestically and internationally, particularly with promising progress in integrating BIM into existing curricula. Domestic research on establishing BIM training platforms/laboratories has also achieved certain results, though literature providing detailed discussions on how to construct BIM virtual simulation training platforms remains relatively scarce.

3.1 Construction Objectives of the BIM Virtual Simulation Training Platform

The construction objectives of the BIM virtual simulation training platform are planned from three perspectives: student capability cultivation, platform function planning, and faculty development:

1. The construction of a BIM virtual simulation training platform for construction management can promote reforms in students' vocational capability cultivation systems and professional practice teaching systems, thereby enhancing students' professional qualities and engineering practice abilities. It also plays an important role in cultivating students' hands-on abilities, communication and collaboration skills, critical thinking, and innovative entrepreneurial spirit.
2. The platform enables simulation of BIM-based project lifecycle management, covering the main business processes of engineering project management throughout the entire lifecycle—including decision-making, design, construction, operation, and maintenance—to comprehensively cultivate students' fundamental abilities in project planning, organization, implementation, and optimization, thereby enhancing their professional competitiveness.
3. The platform aims to cultivate a cohort of "dual-qualified" faculty familiar with BIM technology. Leveraging the BIM virtual simulation training platform constructed through this project, the knowledge system and teaching model of construction management can be optimized to meet new societal demands for high-quality BIM talent cultivation.

3.2 Construction Content of the BIM Virtual Simulation Training Platform

Based on pedagogical research and surveys of employer requirements from multiple construction units, the engineering management BIM virtual simulation training platform is divided into several sub-platforms according to professional training programs and students' basic vocational capabilities. The platform system architecture is illustrated in Figure 1 [Figure 1: see original paper]. The

platform aims to cultivate high-caliber, innovative engineering management professionals with international perspectives, while also contributing significantly to enhancing faculty teaching and research capabilities and building a "dual-qualified" teaching team.

The BIM virtual simulation training platform consists of building structure design sub-platforms, construction process simulation sub-platforms, BIM engineering cost sub-platforms, and BIM integrated project management sub-platforms. Beyond meeting practical teaching requirements, the platform establishes professional competition platforms (supporting BIM application skills competitions, etc.) and enterprise real-project practical platforms to support the cultivation of students' hands-on abilities, communication skills, vocational capabilities, and innovative entrepreneurial spirit. The supporting relationship between the BIM virtual simulation training platform and the cultivation of students' comprehensive capabilities is shown in Table 1 .

The BIM virtual simulation training platform emphasizes different design content according to various universities' cultivation objectives for construction management students. For research-oriented universities, the focus should be on strengthening students' design capabilities, particularly emphasizing the application of information technology in construction management; therefore, the building structure design sub-platform and integrated project management sub-platform should be more comprehensive. For teaching-research universities, the emphasis should be on students' mastery of professional knowledge; thus, training content for the BIM engineering cost sub-platform and integrated project management sub-platform should be expanded. For application-oriented universities, students' practical combat capabilities should be particularly emphasized; consequently, the focus should be on the construction virtual simulation training platform, competition training platform, and enterprise project practical platform.

3.2.1 Building Structure Design Training Sub-platform

Architectural Design Modeling Training: Using Revit, a mainstream BIM modeling software with high market share, as the core, this training platform enables engineering management students to complete architectural design modeling for multi-story student dormitories, high-rise shear wall residential buildings, and single-story industrial plants. Students learn functions such as sunlight analysis, clash detection, evacuation simulation, and energy consumption analysis. Through BIM model walkthrough functions, students gain deeper understanding of architectural design principles and construction requirements.

Basic Structural Design Training: Centered on PK+PMCAD structural modeling and design software, which holds high market share, and supplemented with structural calculation toolbox software, this training platform enables engineering management students to complete structural calculations for multi-story frame structures and multi-story masonry structures, as well as course design

for ribbed floor beam-slab structures. This cultivates students' basic structural design capabilities while enhancing their understanding of collaborative building structure design, improving their modeling and drawing reading abilities, and mastering basic component design principles and methods.

3.2.2 Construction Virtual Simulation Training Sub-platform

Three-Dimensional Construction Site Layout Design: Designing construction site layout plans in a three-dimensional environment better addresses issues such as site functional zoning, internal road planning, and crane trajectory interference. On this training platform, students can complete layout design for multi-story frame structure and single-story industrial structure construction, cultivating their basic construction organization design capabilities.

Construction Scheme Preparation and Simulation: Construction scheme preparation is a critical component of bidding and construction implementation. Due to limited practical experience, engineering management students often find construction scheme preparation challenging. Leveraging a construction scheme preparation system based on case retrieval methods, the platform recommends similar construction scheme templates to improve preparation efficiency. Utilizing BIM construction animation and virtual walkthrough functions, construction scheme simulation can model key construction processes such as hoisting, concrete formwork, steel reinforcement detailing, and concrete pouring. This training platform helps students better understand construction processes and improves their construction scheme preparation capabilities.

3.2.3 BIM Engineering Cost Training Sub-platform

Courses and capability cultivation related to engineering cost represent a distinctive feature of our university's construction management program. The platform is equipped with BIM-based quantity surveying and pricing software capable of importing models from mainstream BIM software (Revit, Tekla, MagiCAD, etc.) to achieve quantity takeoff and pricing. It meets the basic theoretical teaching and practical training (course design) requirements for four engineering cost specialties: building, installation, municipal, and decoration. As an integrated system, the BIM engineering cost platform should interface with the building structure design sub-platform and construction simulation sub-platform.

3.2.4 BIM Integrated Project Management Training Sub-platform

Based on BIM, this sub-platform achieves integrated management of construction projects, covering business areas such as bidding, contract management, project management sandbox simulation, three-dimensional schedule control, cost control, quality management, safety management, and information management. On this platform, students can complete tasks including bid preparation, contract drafting, project management sandbox simulation, schedule planning,

technical-economic scheme comparison and analysis, and construction regulations case analysis, thereby comprehensively cultivating their fundamental abilities in project planning, organization, implementation, and optimization.

4 Cloud-Based BIM Virtual Simulation Training Platform Configuration

Given the characteristics of the BIM virtual simulation training platform—involving numerous software systems, wide application domains, and frequent upgrade services—flexible deployment, timely response, and rapid construction of corresponding hardware and software resources are required. Therefore, we construct a unified virtualized cloud platform across four layers: hardware device layer, software platform layer, basic application layer, and multi-terminal access layer. The hardware device layer consists of various blade servers including file servers, application servers, and Web servers. The software platform layer provides services such as identity authentication, data exchange, and resource scheduling. The basic application layer loads BIM-based virtual simulation training platforms for building modeling, construction sandbox simulation, and engineering cost, as well as competition platforms for BIM application skills contests and building structure design contests, and various project platforms commissioned by enterprises. Under firewall protection, the multi-terminal access layer enables access from various terminals including mobile phones, computers, and tablets through campus networks and the Internet.

To facilitate reference for peer institutions constructing BIM virtual simulation training platforms, our university' s main hardware and software configurations are detailed in Table 2 .

5 Conclusion

As BIM technology applications in the construction industry gradually enter a stage of deepening implementation, societal demand for BIM talent is substantial. The construction of BIM virtual simulation training platforms aims precisely at enhancing students' vocational capabilities. By constructing training sub-platforms for building structure design, construction virtual simulation, BIM engineering cost, and BIM integrated project management, the platform comprehensively covers the main courses in construction management programs. The paper designs a system hierarchy based on cloud architecture and enumerates the main hardware and software components to provide reference for peer institutions establishing similar training platforms. Further research will include developing more types of platform training courses and platform training evaluation mechanisms.

References

[1] Department of Higher Education, Ministry of Education. Notice on Launching the Construction of National Virtual Simulation Experimental Teaching Centers (Jiao Gao Si Han [2013] No. 94) [Z].

[2] Li Yanfeng, Du Xiuli, et al. Exploration and Practice of Constructing Virtual Simulation Experimental Teaching Centers for Civil Engineering Specialties [J]. China University Teaching, 2014, (9): 82-85.

[3] Zhang Shang, Ren Hong, Albert P.C. Chan. Research on BIM-Based Teaching Reform Issues in Construction Management (Part 1) [J]. Construction Economy, 2015, 36(1): 113-117.

[4] Sacks R., E. Pikas. Building information modeling education for construction engineering and management. I: Industry requirements, state of the art, and gap analysis [J]. Journal of Construction Engineering and Management.

[5] Adamu, Z.A., T. Thorpe. How should we teach BIM? A case study from the UK [C]. Washington, DC: The 9th BIM Academic Symposium & Job Task Analysis Review, 2015.

[6] NATSPEC. BIM education - global -2015 update report [R]. NATSPEC Construction Information, 2015.

[7] Ali A., Zia U.D., Rizwan F. Integration of BIM in construction management education: an overview of Pakistani Engineering universities [C]. Phoenix, AZ: International Conference on Sustainable Design, Engineering and Construction, 2016.

[8] Zeng Wenhai, Fu Weiming. Research on BIM Technology Application in University Teaching [J]. Journal of Heilongjiang Vocational Institute of Ecological Engineering, 2014, (6): 85-86.

[9] Sun Liya, Li Xiuqiang, Cheng Guoqiang. Research on Countermeasures for Cultivating BIM Technical Talents in Architectural Vocational Colleges [J]. Journal of Nanyang Normal University, 2015, 14(12): 72-75.

[10] Wang Jingying. Application of BIM Technology in the Course *Architectural Drawing and Construction* [J]. Vocational Technology, 2016, 15(4): 66-68.

[11] Wang Lin, Yang Xianzhong, Miao Lijuan. Research on Application of BIM Technology in Steel Structure Courses in Vocational Colleges [J]. Higher Education Online, 2015, (12): 159-160.

[12] Zhong Wei, Zhang Xinwen, Jiang Tengteng. Research on Application of BIM Simulation in Teaching Reform of Engineering Project Management Courses [J]. Journal of Information Technology in Civil Engineering and Architecture, 2013, (06): 7-11, 34.

[13] Zhu Hongguang, Yi Cheng, Wang Que, et al. Current Application Status and Recommendations of BIM Technology in Civil Engineering Teaching [J].

Education Teaching Forum, 2015, (11): 184-185.

[14] Tu Jinsong, Li Ruixia. Construction of BIM-Based Comprehensive Training Platform for Civil Engineering Specialties [J]. Journal of Hefei University, 2015, 25(3): 76-80.

[15] Chen Liping, Chen Shu. Construction of BIM-Based Teaching and Training Platform for Construction Management Majors [J]. China Science and Technology Education Innovation Herald, 2010, (31): 234-235.

[16] Zhang Jinyu. BIM Talent Training Model for Engineering Cost Majors in Vocational Colleges [J]. Project Management Technology, 2015, 13(7): 27-31.

[17] Bai Quan, Bian Jingmei. Research and Practice of BIM Teaching Reform for Civil Engineering Majors [J]. Journal of Information Technology in Civil Engineering and Architecture, 2017, 9(5): 90-93.

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