The Path and Practice of Cultivating BIM Talents in Civil Engineering Majors at Applied Undergraduate Institutions in the Context of Intelligent Construction

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Abstract. With the rapid advancement of intelligent construction in the building industry, the existing Building Information Modeling (BIM) talent cultivation models and evaluation standards for civil engineering majors no longer meet industry job requirements. This paper analyzes the current state and challenges of BIM talent cultivation in civil engineering majors in China, focusing on four key areas: the curriculum system, practice system, evaluation system, and faculty alignment. Drawing on nearly a decade of exploration and practical outcomes in BIM talent cultivation at Xi'an Eurasia University, this paper proposes a new approach. Key recommendations include revising the training objectives of various majors to align with new BIM job competency requirements, reconstructing the BIM teaching assurance system (encompassing curriculum, practice, evaluation, and assurance systems), establishing a "school-industry-academy-enterprise" tripartite collaborative education model, innovating flexible employment methods to diversify faculty composition, and reaffirming the applied talent cultivation positioning of universities. These proposed paths and models have been implemented at Xi'an Eurasia University, achieving industry-recognized results. This paper aims to provide reference and guidance for similar institutions in exploring BIM talent cultivation under new circumstances.

Keywords: BIM Talent Cultivation, Curriculum System, Educational Model

1 Introduction

The World Economic Forum has developed a framework to transform the construction industry through new technologies, promoting its intelligent transformation and upgrading. Various countries have set goals for intelligent construction transformation. In 2020, the Ministry of Housing and Urban-Rural Development of China, along with 12 other departments, issued the "Guidance on Promoting the Coordinated Development of Intelligent Construction and Construction Industrialization," emphasizing the upgrade of the construction industry towards industrialization, informatization, and intelligence. The intelligent transformation of the construction industry has become an inevitable trend.

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Intelligent construction is an innovative engineering model that integrates the new generation of information technology (such as BIM) with engineering construction (specifically civil engineering)[1]. Its development requires professionals in intelligent construction to possess a T-shaped knowledge structure[2]. The "horizontal" component signifies a broad knowledge base, encompassing the intersection and integration of disciplines such as materials, machinery, and computer science with civil engineering. The "vertical" component represents in-depth expertise in a specific area. Intelligent construction emerges from the deep integration of information technology and engineering construction. Therefore, professionals in this field must master BIM technology and methods, ensuring the seamless integration of information technology with civil engineering knowledge.

Currently, there are significant contradictions between the demand for intelligent construction professionals and the traditional training models for civil engineering majors. BIM technology serves as the primary means and platform for intelligent construction and is crucial for the industry's intelligent transformation. Surveys indicate that both domestic and international construction industries prefer to hire graduates with a BIM knowledge background from civil engineering majors. However, traditional civil engineering programs lack systematic BIM courses, and students do not possess the necessary information technology knowledge to adapt to the current construction industry. This inadequacy prevents them from seizing the opportunities and addressing the challenges brought by the industry's intelligent transformation[3].

Given this context, researching the BIM talent cultivation path for civil engineering majors within the framework of intelligent construction is of significant theoretical and practical importance. This research can address the shortage of intelligent construction professionals and promote the transformation and upgrading of the construction industry.

2 Analysis of the Current State of BIM Talent Cultivation

BIM technology, as an innovative form of intelligent construction, spans the entire lifecycle of construction projects. It is a key technology for the renovation and upgrading of the construction industry and is hailed as the "second revolution" in the construction sector. BIM technology also represents a significant transformation in the cultivation of civil engineering talents under the new engineering education paradigm. It features interdisciplinary integration, professional convergence, and strong practicality[4]. BIM talents do not merely master a single course or skill; their cultivation necessitates a comprehensive reform and upgrade of the traditional professional education system, encompassing the curriculum system, practice system, evaluation system, and faculty alignment.

2.1 Unreasonable Design of BIM Curriculum System

Based on a literature review and surveys[5-7], BIM courses in domestic universities have mainly undergone two stages. The first stage, also known as the BIM Education 1.0

stage, involved adding several BIM courses to the existing civil engineering curriculum. These courses primarily included BIM Introduction, BIM Modeling, and BIM Technology Application. This simple addition of courses somewhat advanced students' BIM skills without significantly disrupting or changing the original teaching arrangements, thus being adopted in the initial phase of BIM education transformation in universities. However, this model did not form a complete and systematic curriculum system and talent cultivation loop. BIM learning and professional learning were relatively disconnected, resulting in students learning some software operation skills but being unable to solve actual project problems.

The second stage, also known as the BIM Education 2.0 stage, involved integrating BIM technology with the existing curriculum system. By optimizing and integrating existing courses, some were removed to make space for a series of BIM courses. Additionally, original courses such as "Architectural Engineering," "Construction Technology," and "Engineering Surveying" were adjusted to include BIM technology methods or BIM application scenarios. Finally, through BIM-focused graduation projects, students' comprehensive BIM capabilities were cultivated. This "professional + BIM" integration method taught students BIM systematic thinking and professional application to a certain extent. However, with the rapid advancement of intelligent construction in the industry, industrialization, intelligence, and informatization have become mainstream demands in engineering construction. In this context, how BIM technology supports the development of intelligent construction and how it is integrated and practiced in the curriculum system is the main task of current curriculum system reform.

2.2 Imperfect BIM Practice System

As a traditional engineering discipline, civil engineering relies heavily on practical experience to achieve its training goals. A relatively mature professional practice system has been established through various inherent stages such as cognitive internships, course practices, production internships, graduation internships, and graduation projects. However, the integration of BIM technology primarily occurs within course modules. Consequently, BIM practice is mainly combined with course practice and does not extend across the entire professional practice system[8].

This limitation has resulted in the absence of a comprehensive professional practice system based on BIM technology, leading to a fragmented understanding and mastery of BIM among students. They perceive BIM mainly as a method of architectural expression, with most of their experience limited to basic software operations. There is minimal exposure to the systematic application of BIM in their profession or its collaborative application across different disciplines.

Furthermore, traditional architectural software training rooms cannot meet the requirements of BIM toolsets and project operations. Consequently, many universities have not fully implemented BIM course practices, leaving students with only theoretical knowledge of BIM. This approach is inadequate for meeting the demands of BIM talent cultivation.

2.3 Incomplete BIM Evaluation System

An incomplete and unreasonable evaluation system in BIM education directly affects the quality of talent cultivation. As previously mentioned, the implementation of BIM in universities mainly focuses on courses such as BIM modeling. Course evaluations generally consist of process assessments and final exams. BIM courses are typically assessed through regular assignments and final computer operations or paper writing, with the final results graded by the course instructor. While this method is suitable for theoretical courses, it is clearly inadequate for courses and competencies that are highly practical and comprehensive, such as those involving BIM.

Firstly, the evaluation subjects are overly singular, with assessments mainly conducted by the course instructor. This lack of diversified evaluation subjects may lead to subjective and biased evaluation results. Secondly, the evaluation content is overly focused on theory and skill operations, failing to comprehensively assess the ability to solve engineering problems using BIM.

3 Mismatch in Faculty Strength

The cultivation of BIM talents started relatively late in China. Currently, most university teachers responsible for teaching have not encountered BIM during their own education. Instead, they have undergone periodic training later on to meet teaching needs. This results in a lack of comprehensive understanding of BIM among faculty members. Additionally, due to the highly practical nature of BIM, a deep understanding of its application processes and value can only be achieved through specific project applications. Most university teachers transition from one academic institution to another and do not deeply understand the current state and pain points of traditional project management. As a result, they cannot effectively combine theory with practice in the implementation process of new BIM technologies, leading to suboptimal outcomes in talent cultivation.

Introducing industry professionals is also a key method for building faculty teams in applied universities. However, the recruitment of industry faculty for the BIM field faces significant challenges. On the one hand, there is a severe shortage of BIM professionals in the industry, and those who meet the technical requirements of universities are rare and highly sought after. On the other hand, as an emerging technology in the construction industry, BIM is primarily engaged by younger professionals who often lack the educational qualifications and titles required by universities. Consequently, there are few candidates who fully meet the schools' requirements.

4 Innovation and Practice in Bim Talant Cultivation Pathways

4.1 Revising Training Objectives Based on BIM Job Competency Requirements

According to different application fields, BIM professionals can be classified into BIM standard-setting talents, BIM tool development talents, and BIM application engineers.

The cultivation of civil engineering professionals mainly targets BIM application engineers, who utilize BIM technology to achieve refined management and efficient construction throughout the entire life-cycle of engineering projects. This requires BIM talents to be comprehensive BIM engineers, proficient in new BIM technologies, concepts, and standards.

The training objectives for civil engineering majors in applied undergraduate universities need to be adjusted based on the competency requirements of BIM engineers. Survey results indicate that current BIM talent cultivation primarily focuses on single-discipline modeling skills and the application of BIM at specific project stages. This approach emphasizes the mastery of BIM modeling abilities and single-discipline application skills. However, it lacks a comprehensive understanding of BIM system thinking, BIM management processes, BIM management value, the data value of the entire life-cycle, and how BIM aids intelligent construction, let alone practical application.

The rapid development of AI technology is poised to replace many modeling tasks and basic applications. In response to the evolving needs of intelligent construction, optimizing the BIM job competency model and revising training objectives is crucial for BIM talent cultivation. This optimization requires a shift from single-discipline operational skills and isolated problem-solving abilities to a focus on the full-process application of BIM and the value of BIM data. Additionally, it involves fostering students' abilities in interdisciplinary and multidisciplinary collaboration and continuous learning.

The key competencies required for BIM professionals include basic BIM skills (modeling and data collection), professional application skills (system thinking and professional scenario understanding), and innovation skills (data value and professional collaboration). These competencies, tailored to the varying focuses of different civil engineering majors (technical and managerial), necessitate a revision of training objectives. This revision will underpin the reconstruction of the curriculum system and the innovation of cultivation models.

4.2 Building the BIM Teaching Assurance System for Each Major

To meet BIM job competency requirements, a multidimensional composite BIM teaching assurance system has been established for civil engineering majors[9]. This system encompasses the curriculum system, practice system, evaluation system, and a comprehensive implementation assurance system, providing a robust BIM information foundation for cultivating versatile talents in intelligent construction.

The system aligns BIM foundational courses, BIM application courses, and BIM comprehensive courses with job competency requirements. Core BIM foundational courses include Professional Introduction, BIM Modeling Technology, Multidisciplinary BIM Modeling, and BIM Visualization. Core BIM application courses encompass BIM-assisted Collaborative Design, BIM and Civil Construction Application, BIM and MEP Construction Application, and Digital Construction. Core BIM comprehensive courses cover BIM-based Prefabricated Structure Design, Intelligent Structure Design, BIM-based Full-process Cost Management, BIM-based Project Construction Management, Internship, and Graduation Design. These courses are delivered in various formats and locations based on content requirements and evaluation characteristics.

BIM foundational courses are primarily conducted in classrooms or computer labs by university instructors and are assessed accordingly. Credits for modeling courses can be exchanged for industry BIM modeling certifications. BIM application courses involve both theoretical classroom learning and project-based learning on specialized school-enterprise practice platforms (such as industry colleges, BIM studios, and BIM training labs). Final assessments include project reports and defenses, with grades jointly assigned by course instructors and enterprise mentors. Credits can also be exchanged for other training forms, such as BIM certificates and competition awards.

BIM comprehensive courses feature short-term projects and graduation designs for each major. Short-term projects are executed through team collaboration in a project-based format, while graduation designs are guided by both university instructors and enterprise mentors during the senior internship stage. These projects are based on real enterprise needs. Graduation design organization can be individual or cross-disciplinary team-based, depending on the internship unit's requirements and the student's professional background. The specific framework of the teaching assurance system is illustrated as Figure 1.

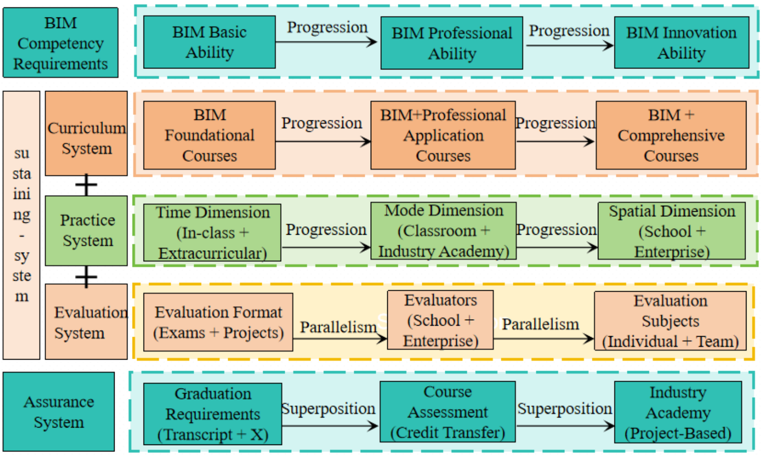

Fig. 1. Multidimensional Composite BIM Teaching Assurance System for Civil Engineering Majors.

4.3 Constructing a "Tri-fusion" Collaborative Education Model

The traditional model of learning theory in school and practicing through internships is no longer sufficient to meet the industry's demand for compound BIM talents. Based on practical experience and enterprise employment needs, schools should establish a third-party platform that integrates efforts from both academic and corporate sectors.

This platform could be modern industry colleges, provincial engineering research centers, or provincial innovation studios, promoted by the state as training platforms. This forms a "tri-fusion" collaborative education model [10], which introduces a third element to the original dual system of school and enterprise, creating a "triadic system."

The first element is the school, the second is the enterprise, and the third is the industry academy or other platforms for industry-education integration. These three educational entities alternately and proportionately participate in the entire talent cultivation process. Driven by both the talent supply side and industry demand side, the "tri-fusion" talent cultivation model is constructed, combining school (theory and foundational application), industry academy (application and comprehensive skills), and enterprise on-site training (comprehensive skills and professional qualities) (Figure 2).

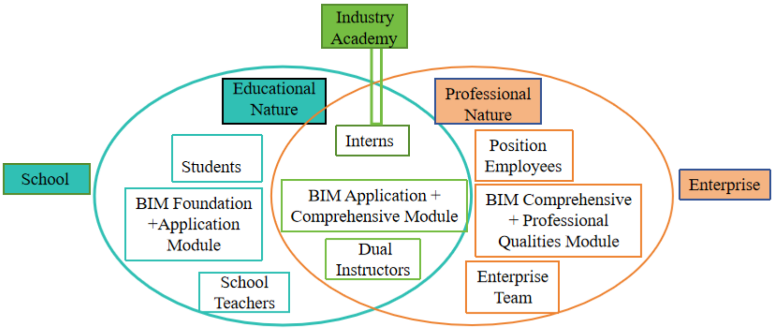

Fig. 2. "Tri-fusion" Talent Cultivation Model.

4.4 Faculty Enhancement

Introducing Industry Faculty. The cultivation of talents in applied universities relies heavily on an applied faculty team. However, existing university faculty teams are primarily focused on traditional teaching and research, with relatively weak practical abilities. To address this issue, universities should actively introduce BIM practitioners and industry experts with extensive experience to participate in the design and implementation of BIM courses. These professionals bring substantial practical experience and deep expertise, injecting new vitality into the academic work of universities. Their involvement not only enhances the teaching and research levels of higher education institutions but also provides students with more practical opportunities and career guidance.

For BIM specialists, universities can adopt flexible employment policies. For example, at Xi'an Eurasia University, where the author works, the recruitment of full-time teachers primarily requires a graduate degree or higher. However, for industry professionals in the BIM field, the educational requirement can be relaxed to a bachelor's degree, provided they meet the criteria for work experience and project involvement, with a requirement of intermediate-level professional titles or higher. The inclusion of industry faculty has significantly alleviated the shortage of BIM faculty and the challenges in conducting BIM training projects at the university.

Transition of In-house Faculty. In-house faculty play a crucial role in talent cultivation at universities. In the context of intelligent construction, helping in-house faculty transition to meet industry needs and keep up with industry trends is essential for university development and the faculty's personal growth. Universities can facilitate this transition by providing performance incentives and institutional support to enhance faculty's professional knowledge and practical abilities.

For instance, universities can motivate faculty to participate in research projects and practical activities through performance-oriented incentives and institutional guarantees. This includes involvement in industry-collaborative horizontal projects and on-the-job training at enterprises. By participating in research projects and practical activities, faculty can stay updated on the latest developments in intelligent construction and integrate these advancements into their teaching, thereby broadening students' knowledge.

At the author's institution, faculty are encouraged to obtain industry BIM certifications, participate in BIM skills training, and engage in BIM project internships through measures such as performance bonuses, doubled hours for new BIM courses, and matched funding.

5 Achievements in Innovative Bim Talent Cultivation

Taking Xi'an Eurasia University as an example, the university officially incorporated the BIM curriculum system into the talent cultivation programs for civil engineering majors in 2015. By jointly establishing a BIM center practice platform with enterprises and creating an intelligent construction industry academy, the university has achieved significant results in student development, curriculum construction, and faculty training.

5.1 Student Development

Students undergo a progressive BIM learning process through four stages: classroom BIM foundational learning, professional training in studios, comprehensive projects in the industry academy, and practical job experience in enterprises. By the time they graduate, students will have completed the required BIM courses, obtained at least one industry BIM certification, participated in at least one provincial or higher-level BIM competition, completed at least one real BIM service project, and undertaken a six-month BIM internship in an enterprise.

5.2 Curriculum Development

BIM talent cultivation relies heavily on the support of robust BIM courses. After nearly ten years of development and accumulation, the university has created a series of BIM modeling courses, professional application courses, and comprehensive practice courses. The concepts and content of these courses have been shared with the broader community over 30 times, generating economic value exceeding 500,000 yuan. The recipients include institutions such as Xi'an University of Science and Technology and enterprises like China State Construction Engineering Third Bureau. Notably, the course "Building Information Modeling" has been recognized as a provincial first-class course and received the National Outstanding Course Award for Applied Reform in 2022.

5.3 Faculty Development

Through the introduction of industry faculty and the transition of in-house teachers, the university currently has 15 faculty members specializing in BIM, all of whom have obtained industry-recognized BIM skill certificates. In addition to regular BIM course teaching, the BIM faculty team is also involved in BIM research and social services. The university has established a comprehensive industry-education integration model for faculty development, where teachers take on multiple roles to effectively enhance their BIM expertise, thereby supporting the university's BIM talent cultivation.

Moreover, the expansion of BIM external services and research has helped identify more enterprise needs for BIM professionals, laying a solid foundation for student internships and employment. This effectively ensures a closed-loop process for professional BIM talent cultivation, from "entry" to "exit."

6 Conclusion

In summary, intelligent construction is a crucial direction for the development of new building industrialization, and the exploration and practice of intelligent construction cannot succeed without the support of BIM technology talents. Currently, most applied universities with civil engineering majors have incorporated BIM into their curricula and are gradually exploring new BIM talent cultivation models and course-certification integration reforms. Although BIM talent cultivation is still in the exploratory stage and faces challenges such as insufficient course resources, inadequate training conditions, and underdeveloped school-enterprise cooperation, it has generally taken the right path.

To ensure that BIM talents can meet the demands of the new era of building industrialization and digitalization, the cultivation pathway should be guided by industry needs, emphasizing the development of core job competencies. This includes proficiency in BIM technology, a thorough understanding of project management processes in the construction and engineering industry, and the enhancement of collaborative communication and innovative thinking skills. Universities should strengthen cooperation with the industry to provide more practical opportunities for students, promote the organic combination of theory and practice, and improve the technical application abilities and problem-solving skills of BIM talents, thereby providing the construction industry with high-quality professionals with specialized skills.

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