Education Reform and Development, 2025, Volume 7, Issue 3
https://ojs.bbwpublisher.com/index.php/ERD
Online ISSN: 2652-5372
Print ISSN: 2652-5364

BIM-Based Visualization in Civil Engineering Drawing Course: Teaching Innovations and Practical Implementation

Fujian Yang[1], Yi Bao[1], Xiaoshuang Li[1], Rui Wang[2]*, Yong Wei[1]

[1]School of Urban Construction, Changzhou University, Changzhou 213164, China
[2]Wang Zheng School of Microelectronics, Changzhou University, Changzhou 213164, China

***Corresponding author:** Rui Wang, wangrui@cczu.edu.cn

Abstract: This study explores the integration of Building Information Modeling (BIM) technology into the civil engineering drawing course to cultivate high-quality, application-oriented professionals with strong innovation and practical skills. The research focuses on reforming multiple dimensions, including the teaching content system, specialized instructional materials, pedagogical models, and assessment methods. The objective is to enhance the effectiveness of civil engineering graphics education while providing valuable practical experience and a reference framework for other civil engineering courses incorporating BIM applications. This study holds significant theoretical and practical value in addressing the evolving demands of engineering education within the context of emerging engineering disciplines and in fostering students' comprehensive abilities.

Keywords: BIM technology; Civil engineering graphics; Emerging engineering disciplines; Curriculum reform

Online publication: April 2, 2025

1. Introduction

Building Information Modeling (BIM) is a groundbreaking concept and technology that has revolutionized the architecture industry in the 21st century, attracting widespread attention from both academia and the engineering sector worldwide [1]. The origins of BIM can be traced back to the 1970s in the United States, when Dr. Charles Eastman of Carnegie Mellon University first introduced the concept [2]. According to the National BIM Standard of the United States [3], BIM is defined as a digital representation of a building facility's physical and functional characteristics. Serving as a shared knowledge resource, BIM provides a consistent and reliable foundation for informed decision-making throughout the lifecycle of a facility.

With the Ministry of Education actively promoting the development of new engineering disciplines, traditional civil engineering drawing course must be timely updated and adapted to meet the evolving requirements for cultivating application-oriented professionals [4]. Integrating BIM technology into these courses can greatly enhance students' comprehension of spatial structural relationships while effectively addressing the challenges associated with interpreting 2D projection drawings. By leveraging BIM-generated digital parametric models, students can dynamically visualize 3D building structures and gain a comprehensive understanding of each component's intricate details. This approach facilitates a seamless transition between 2D engineering drawings and 3D building models, offering an intuitive and effective learning experience. Therefore, conducting an in-depth analysis of the current applications and future development trends of BIM technology—while identifying and overcoming its challenges in civil engineering drawing education—is of significant theoretical and practical value. Such efforts will promote the widespread and in-depth integration of BIM technology in civil engineering education in China.

2. Development trends of BIM technology

As a cutting-edge tool and production methodology shaping the future of the construction industry, BIM technology has had a profound global impact since its inception. Its rapid development, particularly between 2002 and 2009, marked a transformative period for the industry worldwide [5]. In the United States, for instance, the General Services Administration (GSA) initiated the 3D-4D-BIM program in 2003 and subsequently issued a series of related guidelines to facilitate its adoption [6]. By 2007, the U.S. government mandated that all large-scale projects meeting the bidding threshold must incorporate BIM technology. Furthermore, the GSA actively promoted the adoption of 3D-4D-BIM through financial incentives and other forms of support, significantly accelerating the widespread implementation of BIM across the engineering sector in the United States.

With the advancement of globalization, China officially introduced BIM-related software in 2004, marking the initial contact with BIM technology. In May 2009, the key project of the "11th Five-Year Plan" for National Science and Technology Support, titled "Research on Key Technologies for Modern Architectural Design and Construction," was launched in Beijing, which explicitly stated the need for in-depth research on BIM technology and the use of its collaborative design platform to improve the quality and efficiency of building production. During the "12th Five-Year Plan" period, China achieved widespread application of BIM technology in the construction industry and accelerated the promotion of collaborative design and visualization technologies in the engineering sector. In August 2016, the Ministry of Housing and Urban-Rural Development issued the "2016–2020 Outline for the Development of Information Technology in the Construction Industry," further setting the goal of "focusing on the development of BIM." In 2017, the Ministry approved the "Building Information Modeling Construction Application Standards" as a national standard, which officially came into effect on January 1, 2018, marking significant progress in the standardization of BIM in China.

In China, the promotion and application of BIM technology has not only attracted widespread attention in the engineering sector but also actively engaged higher education institutions in exploring and researching this technology. Li *et al.* [7] established the Virtual Construction Laboratory, conducting extensive research on BIM-based virtual visualization construction technologies. They introduced 3D video effects into the virtual construction process, effectively enhancing the realism and effectiveness of virtual construction. He *et al.* [8] summarized the current shortcomings in architectural engineering construction based on the research and development status of BIM technology in China and proposed a BIM-based engineering management framework. Gao *et al.* [9] used BIM-based visualization programming algorithms to determine the installation sequence and positioning of prefabricated components, and through simulation experiments, developed a lightweight structure robot intelligent construction method, achieving an obstacle avoidance technique for assembly paths more suitable for building applications. Universities such as Shanghai Jiao Tong University, Chongqing University, Southwest Jiaotong University, Huazhong University of Science and Technology, and Tianjin University have also established BIM research institutions and engineering laboratories, conducting in-depth exploration of BIM technology in areas such as usage standards, application methods, and management frameworks. These efforts have collectively contributed to the ongoing development and innovation of BIM technology in China.

3. Overview of civil engineering drawing course

The civil engineering drawing course is a fundamental subject specifically designed for students in civil engineering programs. Its core objective is to study how to represent buildings and structures from actual engineering projects on a plane. The course content is divided into two parts: descriptive geometry and civil engineering drawing. The descriptive geometry section aims to develop students' spatial imagination, logical thinking, and the ability to visualize three-dimensional geometric shapes, serving as the foundation for the projection theory in civil engineering drawing. It is characterized by its strong practical nature and theoretical complexity. The course focuses on real engineering case studies, guiding students on how to accurately interpret and precisely draw architectural, structural, and equipment construction drawings. These cases represent real-world three-dimensional structures, but students are exposed to their two-dimensional representations in this course. Throughout this process, students are encouraged to use their spatial imagination to compare two-dimensional drawings with three-dimensional physical structures, thereby absorbing all the information from the drawings. The course aims to systematically develop students' knowledge in drawing and reading drawings, enabling them to not only read but also create two-dimensional engineering drawings, laying a solid foundation for engineering drawing expertise. Zhao *et al.* [10] have addressed the issue of unclear expression in traditional construction drawings by proposing solutions that utilize BIM technology to return two-dimensional structural construction drawings to their three-dimensional forms, further emphasizing the importance of BIM technology in civil engineering drawing education. As a medium for engineering communication, drawings are not only tools for information transfer but also the technical foundation for students to learn higher-level professional courses. In the process of learning to read and draw, students must not only possess strong spatial imagination and logical thinking abilities but also develop an in-depth understanding of spatial relationships, as this process is closely linked to engineering practice.

4. Analysis of barriers to the application of BIM in engineering drawing courses

Considering the current state of BIM software and its model visualization capabilities, the integration of BIM into civil engineering drawing education faces several key challenges.

4.1. Low student acceptance

The civil engineering drawing course is primarily designed for first-year civil engineering undergraduates who have just completed their foundational courses and are beginning to explore professional knowledge. At this crucial stage of learning, students are eager to understand their future career fields but often lack a deep comprehension of engineering concepts. Although BIM technology is expected to replace CAD as the next mainstream tool, its integration into civil engineering graphics education remains underdeveloped.

In China, the predominant teaching model for civil engineering drawing heavily relies on instructor-led lectures, leading to low student engagement and limited hands-on practice. As a result, most students do not actively explore CAD and BIM technologies outside the classroom, hindering their deeper understanding and mastery of both the course content and software applications. Compared to international educational approaches, civil engineering drawing education in China needs to place greater emphasis on interactive learning and practical experience. Strengthening student participation and hands-on training will foster a more comprehensive understanding of professional knowledge and enhance students' ability to apply it effectively.

4.2. Variety of BIM software

The implementation of BIM technology differs significantly from CAD technology. CAD technology typically relies on a single or a few software tools, while BIM technology mainly depends on a range of diverse software applications [11], such as design and modeling software, analysis software, collaboration and project management software, rendering and visualization software, and facility management software. Currently, the market offers not only a wide variety of core BIM modeling software but also many interoperable industry-specific software tools. In civil engineering graphics curriculum, the visualization application of BIM is particularly crucial. However, for students just beginning to explore BIM, selecting software that suits their needs is not an easy task. This situation highlights the challenges students face in learning BIM technology and points to issues that need to be addressed in the teaching process.

4.3. Lack of teaching resources

In recent years, Li *et al.* [12] conducted a survey of over 200 universities across China. The survey results revealed that only 16.46% of teachers in this field are proficient in BIM technology. Many universities face significant shortcomings in building a teaching staff proficient in BIM technology. The number of BIM teachers is severely insufficient, and their proficiency in BIM technology is lacking, especially in terms of practical experience in relevant engineering fields, such as architectural design, construction management, cost management, and project management. These factors collectively lead to weak capabilities in applying BIM technology. Additionally, these teachers have relatively few opportunities to receive BIM training, with only 6.33% of teachers in this field receiving three or more BIM training sessions annually. This has become a key factor limiting BIM talent cultivation in universities. Therefore, to improve the effectiveness of BIM education in higher education institutions, there is an urgent need to strengthen the development of teaching staff, particularly by enhancing teachers' application capabilities in BIM technology and their relevant engineering practical experience.

4.4. Lack of high-quality in-depth school-enterprise collaboration in BIM talent cultivation

The integration of industry, academia, and research is the driving force for applied undergraduate institutions to cultivate application-oriented talent and promote the development of their fields, with school-enterprise cooperation being a necessary pathway to achieve this goal [13]. Particularly in the field of BIM technology education, deep school-enterprise collaboration is considered key to the successful application of BIM technology and the development of BIM education in higher education institutions. This cooperative relationship should be based on the principles of "voluntary participation, shared risks, complementary strengths, and shared benefits" to ensure a precise alignment between education and industry needs. However, existing survey results indicate that cooperation between universities and enterprises is still insufficient, particularly at the high-level collaboration with construction enterprises, which is almost nonexistent [14]. This severely limits the relevance and effectiveness of BIM talent cultivation.

To cultivate professionals that meet industry demands, a deep-level cooperation mechanism between universities and enterprises needs to be established and strengthened. Universities should actively connect with well-known companies in the industry, such as China Railway First Group, Shanghai Construction Group, and Shen Yuan Engineering Project Management Company, to jointly create high-quality internship and training bases. By participating in actual engineering projects of partner companies, both faculty and students can engage in practical learning, gaining a deeper understanding of project needs and mastering the application of BIM technology in real-world environments. Such practical teaching not only improves students' understanding of the practical applications of architectural drawing but also develops their problem-solving abilities and teamwork skills.

School-enterprise cooperation also provides students with a platform to interact with industry experts. Enterprises can send technical personnel to directly guide students' practical activities, offering feedback and career advice. This interaction helps students understand industry standards, learn from expert experiences, and improve their technical skills and professional qualities. Furthermore, the practical projects provided by enterprises offer students excellent opportunities to showcase their BIM skills and develop problem-solving and teamwork abilities. By participating in architectural design competitions or collaborative design of real construction projects, students can grow in real-world work environments, laying a solid foundation for their future career paths.

5. Reform ideas for civil engineering drawing education in the BIM era

5.1. Revision of the engineering drawing curriculum outline

The original course content primarily focused on descriptive geometry, basic professional drawing, professional construction drawings, and AutoCAD engineering drawing. Under the AutoCAD-dominated teaching model, students were able to develop certain spatial thinking abilities and proficiency in national drawing standards. However, a survey on the learning outcomes of students at Shenyang Jianzhu University [15] found that students' ability to read floor plans was still weak, and they struggled to establish clear 3D representations when faced with slightly more complex floor plans. To address these challenges, we propose introducing BIM technology, particularly REVIT software, into the curriculum. This change will modernize the teaching content and better meet students' needs. Introducing REVIT software into the civil engineering drawing course will enable synchronized teaching of 3D modeling and 2D engineering drawing interpretation. Through specific engineering case studies, the teaching content will be divided into key elements, such as elevation, axis grids, walls, doors, windows, and columns and beams, guiding students to progressively learn basic operation commands in accordance with the project process while engaging in drawing and modeling. This approach allows students to learn 3D modeling of buildings while intuitively applying these tools to understand 2D engineering drawings.

Therefore, the focus of this course shifts from interpreting architectural components in traditional 2D engineering drawings to understanding the overall structure and function of buildings, emphasizing engineering thinking and the importance of collaborative design. Students will not only learn how to use this auxiliary tool to enhance spatial imagination and engineering cognition but also develop BIM-based engineering project design concepts. The 3D models created by REVIT software can be directly converted into 2D engineering drawings, reducing the emphasis on AutoCAD in the course and streamlining the CAD-related content. Additionally, considering the Western origins of REVIT software, which may result in its drawings not fully conforming to domestic standards, we will also teach relevant editing and adjustment commands in the course to ensure students can modify the drawings to meet national standards. This teaching reform aims to help students master the key knowledge of civil engineering drawing more comprehensively and efficiently.

5.2. Modify the teaching model of engineering drawing

To effectively address the pressure of increased teaching hours for BIM software, we plan to implement a blended teaching strategy combining online and offline methods, aiming to improve teaching efficiency and meet comprehensive teaching needs. In this model, AutoCAD teaching will be delivered through videos produced by our course team, while the teaching of REVIT software will rely on the "BIM Technology Fundamentals - REVIT Architecture" online course on the China University MOOC platform [16].

Using the "Rain Classroom" teaching tool, instructors will send pre-class materials to students, including videos and quizzes, encouraging them to self-study during their free time. Students will also prepare by completing tasks assigned by instructors and practicing with the software in advance. This approach allows students to grasp the basic applications of the software outside the classroom. During classroom teaching, "Rain Classroom" will facilitate interactive communication between instructors and students, including student presentations, in-depth explanations of key points by instructors, and real-time assessments of student performance. After class, instructors can assign homework and provide supplementary materials through the platform, ensuring continuous learning support throughout the course. This blended teaching model not only enhances interactivity and efficiency in teaching but also supports continuous improvement and optimization of teaching quality through comprehensive data collection and evaluation.

5.3. Increase the practical hours for engineering drawing

The core objective of the civil engineering drawing course is to cultivate students' spatial thinking abilities, enabling them to understand and visualize three-dimensional structures through graphical representation. The course aims to systematically equip students with the foundational knowledge of drawing and interpreting drawings, while also developing their basic skills and literacy in engineering drawing, with an emphasis on enhancing spatial imagination and analytical abilities. With the integration of BIM technology, the course should include more practical components, strengthening students' hands-on skills and stimulating their spatial thinking through active engagement.

The study adopts a "unity of knowledge and action" teaching approach, emphasizing the coordination between hands and mind. From the beginning of the course, we increase the time for students to engage in modeling tasks, aiming to cultivate their independent learning abilities and practical skills. The course sets clear requirements for practical hours, including preparatory work, hands-on operation, and classroom interaction. For complex knowledge points, we design "project assignments" to encourage students to collaborate in teams, strengthening their logical thinking abilities and improving learning outcomes through report presentations. In these tasks, students not only enhance their practical skills and teamwork spirit, but also improve their ability to identify, analyze, and solve problems. This will lay a solid foundation for their future professional learning and practical activities, while also promoting the development of their overall engineering literacy.

5.4. Improve the grading system for engineering drawing

With the deeper integration of BIM technology into engineering drawing courses, the traditional assessment model, which primarily relies on written exams, no longer meets the teaching needs of the BIM era. Relying solely on exam scores to assess students' theoretical knowledge does not fully reflect their practical operation abilities. Therefore, the grading system of this course needs to be adjusted to better align with the teaching characteristics after the integration of BIM technology.

We have reconfigured the composition of the total grade, adjusting the ratio of regular performance to final exam scores from the original 7:3 to 5:5. This means that both the final written exam and regular performance will each account for 50% of the overall evaluation. Regular performance includes various aspects such as class attendance, participation, BIM model creation, project practice, and hand-drawn assignments. This reform aims to encourage students to not only study theory but also actively master BIM-related skills, cultivating high-level application-oriented talents that meet societal needs. We hope that this approach will effectively enhance students' comprehensive professional abilities, laying a solid foundation for their future career development.

6. Conclusion

The introduction of BIM technology is not merely a tool innovation but a fundamental transformation of production content and methods. It replaces the traditional CAD era "drawing board" with a collaborative 3D platform and substitutes traditional "drawings" with dynamic, multidimensional, real-time "parametric models." This transformation presents unprecedented challenges and opportunities for our course teaching.

The reform of practical case-based teaching represents an innovative educational practice. This reform encompasses comprehensive updates to teaching content, methods, processes, and evaluations, driving the construction of a knowledge system, the training of thinking skills, the development of abilities, and the shaping of emotions and values from a functional perspective. In terms of teaching content, the reform ensures a close alignment between classroom instruction and workplace demands. On the organizational level, it emphasizes a "teacher-guided, student-centered" teaching philosophy, effectively meeting the needs of professional courses in developing students' technical skills, business management abilities, and job competencies. Through the implementation of such teaching reforms, we aim to better support students, enabling them to confidently face future challenges in the construction industry and continue growing in an ever-evolving technological environment.

Funding

2023 Annual Changzhou University Education and Teaching Research Project (Project No.: GJY2023018, GJY2023002); Ministry of Education Industry-Academia Collaborative Talent Development Program (Project No.: 231107622152200); 2024 Annual Changzhou University Education and Teaching Research Project (Project No.: GJY2024002); 2023 Ministry of Education Industry-University Cooperation Collaborative Talent Cultivation Project (Project No.: 230803975185316); 2024 Ministry of Education Third Phase Supply-Demand Alignment Employment Talent Cultivation Project (Project No.: 2023122876207)

Disclosure statement

The authors declare no conflict of interest.

References

[1] Azhar S, 2011, Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry. Leadership and Management in Engineering, 11(3): 241–252.

[2] Li J, 2014, The Pioneer of BIM – Professor Charles Eastman. Journal of Information Technology in Civil Engineering and Architecture, 6(4): 114–117.

[3] East B, Smith D, 2016, The United States National Building Information Modeling Standard: The First Decade. 33rd CIB W78 Information Technology for Construction Conference (CIB W78 2016), Brisbane.

[4] Yang F, Zhao H, Liu S, et al., 2023, Teaching Reform of Civil Engineering Drawing Under the Background of New Engineering. The Guide of Science & Education, 2023(6): 108–110.

[5] Yang Q, 2016, Applied Research on BIM-Based Collaborative Visualization Design, thesis, Southwest Jiaotong University.

[6] Xie Y, Li C, Li Z, 2017, Smart Building Materials of BIM and RFID in Lifecycle Management of Steel Structure. Key Engineering Materials, 723: 736–740.

[7] Li M, Yu QJ, 2020, Problems and Countermeasures in BIM Technology Application and Talent Cultivation at Architectural Universities. Contemporary Education Research and Teaching Practice, 2020(8): 71–72.

[8] He Q, Qian L, Duan Y, et al., 2012, Current Situation and Barriers of BIM Implementation. Journal of Engineering Management, 26(1): 12–16.

[9] Gao Y, Shu J, Yu K, et al., 2022, Research on Robotic Construction of Light Weight Structures Using BIM Visual Programming. Journal of Building Structures, 43(S1): 296–304.

[10] Zhao Z, Jia J, Zhang X, 2011, Virtual Reality of RC Frame Structure Based on BIM. Journal of Information Technology in Civil Engineering and Architecture, 3(4): 72–75.

[11] He G, 2010, BIM and BIM Software. Journal of Information Technology in Civil Engineering and Architecture, 2(4): 110–117.

[12] Li M, Guo H, Huang T, et al., 2010, Virtual Construction Technology: A Driving Force in Advancing the Building Industry. Informatization of China Construction, 2010(2): 46–51.

[13] Gan R, Huang K, Jin W, et al., 2016, Application of BIM Technology in the Course of Civil Engineering Drawing. Journal of Information Technology in Civil Engineering and Architecture, 8(5): 103–106.

[14] Wu Z, Huang C, 2014, The Concept and Cultivation of Applied Talents. Research in Higher Education of Engineering, 2014(2): 66–70.

[15] Wang J, Zhang D, Zhou J, 2017, Using BIM Technology to Explore the Teaching Reform of Specialized Curriculum in Architectural Universities: Taking Shenyang Jianzhu University as an Example. Journal of Architectural Education in Institutions of Higher Learning, 26(1): 161–164.

[16] Wang D, Yuan Y, Wu Y, et al., 2022, Exploration and Practice of Civil Engineering Drawing Course Reform Based on BIM. Journal of Higher Education, 8(36): 146–150 + 154.