Education Reform and Development, 2026, Volume 8, Issue 7
https://ojs.bbwpublisher.com/index.php/ERD
Online ISSN: 2652-5372
Print ISSN: 2652-5364

Innovation of Teaching Model Empowered by BIM+XR for the Course "Architectural Structure and Drawing Recognition"

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Abstract: Architectural Structure and Drawing Recognition is a core fundamental course for civil engineering majors. Conventional teaching models are plagued by prominent drawbacks including great difficulty in interpreting two-dimensional drawings, weak practical teaching sessions, and simplistic assessment methods, which fail to meet the training requirements for compound skilled professionals. Guided by constructivist learning theory and CDIO engineering education philosophy, this study integrates digital technologies such as Building Information Modeling (BIM) and Extended Reality (XR) to construct an innovative three-stage and five-dimensional digital teaching model. The model consists of three major teaching phases: knowledge transmission, problem inquiry, and practical application. Augmented Reality (AR) is adopted to realize graphic labeling and interpretation; Mixed Reality (MR) is utilized to simulate real construction scenarios; and Virtual Reality (VR) virtual simulation laboratories are deployed to carry out hands-on training. Meanwhile, a comprehensive evaluation system covering five dimensions — spatial transformation efficiency, understanding of construction specifications, application of industry standards, teamwork capability, and innovation potential — is established to comprehensively assess students' learning outcomes. Practical data demonstrate that after adopting this teaching model, students' efficiency in reading complex architectural drawings rises by 42%, and the drawing accuracy of architectural detail drawings increases by 35%. In addition, students' psychological burden arising from industrial technological iteration is significantly relieved, with their anxiety index dropping by approximately 28%.

Keywords: BIM technology; XR technology; Architectural structure and drawing recognition; Digital teaching

Online publication: August 13, 2026

1. Introduction

With the continuous advancement of digital transformation in the construction industry, comprehensive digital upgrading will be vigorously promoted during the 15th Five-Year Plan period, targeting the full digital transformation of the entire industrial chain by 2030. Statistics released by the China Construction Industry Association reveal that the application rate of Building Information Modeling (BIM) technology in China's construction sector has exceeded 60% to date, while the proportion of newly signed prefabricated construction projects remains above 24% [1]. There is an urgent demand for talent proficient in both traditional civil engineering skills and digital information technology.

Current civil engineering curricula have inherent deficiencies that cannot fully adapt to the practical needs of disciplinary development. Research indicates that most students lack spatial cognition when interpreting two-dimensional construction drawings based on plane methods, and nearly 60% fail to form corresponding three-dimensional structural models accurately. Restricted by insufficient training site resources, inadequate capital investment and rapid technological updates, visual and interactive demonstration functions cannot be fully exerted in practical teaching. The existing assessment system still takes two-dimensional drawing skills as the core indicator while paying insufficient attention to students' three-dimensional spatial thinking capacity, and comprehensive evaluation results cannot fully reflect students' potential in spatial cognition [2]. Therefore, the integration of BIM and XR technologies has become a crucial breakthrough to improve teaching quality [3]. It not only conforms to the national strategy of integrating information technology with vocational education for educational development, but also lays a solid foundation for cultivating compound digital talents.

2. Construction of digital teaching system

2.1. Integrated architecture of BIM+XR technologies

Taking the course Architectural Structure and Drawing Recognition as the research object, this paper explores feasible paths for the digital transformation of the course. By integrating BIM and XR technologies, an interactive teaching system is established, with targeted teaching improvement measures designed for different learning stages.

2.1.1. Design of technology selection matrix

Based on the core elements of constructivist learning theory and situated cognition theory, an adaptation model covering three dimensions — technical attributes, operating procedures and functional characteristics — is constructed, as shown in **Figure 1**.

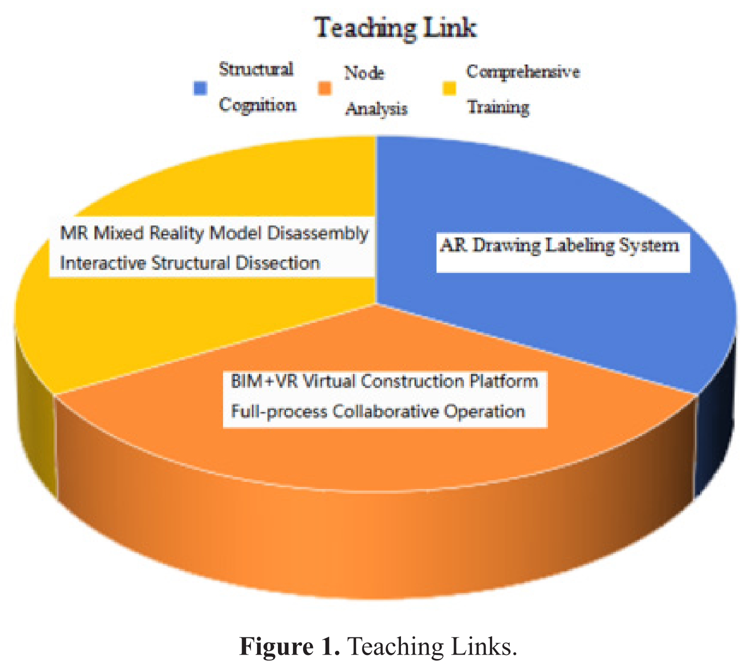

Figure 1. Teaching Links.

Cutting-edge information technologies are adopted to reform talent training modes. The AR-assisted drawing interpretation system integrates three-dimensional modeling with two-dimensional drawings to present the spatial positions and geometric characteristics of components, resolving difficulties caused by limited spatial cognition in conventional teaching [4]. Based on Microsoft HoloLens and other devices, the MR virtual training platform for architectural node disassembly builds immersive interactive environments, enabling students to grasp the spatial layout of structural components, connections between functional modules and construction assembly procedures. A virtual reality platform is built on Autodesk Revit to create immersive virtual workspaces close to real construction sites, providing teachers and students with all-round multi-mode operation experience [5].

2.1.2. Logic of technology integration

This research constructs a technical system guided by the idea of virtual-real integration and intelligent collaboration [6]. AR technology realizes static projection conversion from two-dimensional information to three-dimensional space; MR technology supports dynamic analysis and interactive presentation of multi-dimensional data; VR technology delivers virtual training environments. This mechanism covers three layers of perception, cognition and operation, forming a full-process capacity enhancement system.

2.2. Three-stage progressive teaching model

Combining the CDIO engineering education model with OBE teaching philosophy, a three-tier curriculum system integrating cognition, analysis and practical application is built [7].

2.2.1. Cognition stage: Breakthrough of spatial conversion

This stage focuses on improving students' capability to convert two-dimensional planar graphics into three-dimensional spatial forms. A BIM component library is established to integrate three-dimensional model resources [8]. Enscape is utilized to create immersive virtual training environments for analyzing projection principles and geometric transformation rules, so as to enhance students' spatial cognition ability [9]. After systematic training, participants achieve remarkable improvements in spatial thinking tests [10].

2.2.2. Analysis stage: In-depth interpretation of structural nodes

The Microsoft HoloLens platform is applied to explore interpretation approaches for key component connection nodes, advancing students' understanding of engineering expertise [11]. First, AR technology is used to obtain spatial position information of target nodes; then Mixed Reality (MR) technology disassembles nodes into individual construction procedures, followed by evaluation in accordance with construction standards and quality control specifications. Research shows that students' accuracy in understanding structural nodes rises significantly from 54.3% to 86.7%.

2.2.3. Application stage: Alignment with vocational competencies

Supported by BIM vocational skill certification standards and core post competency requirements, a modular teaching system is constructed. Autodesk Revit is adopted to build full-life-cycle digital twin models of entire projects for spatial collision detection and comprehensive pipeline optimization design. Students are divided into project teams with clear task division, and teachers provide real-time interaction and supervision to implement an integrated teaching model of teaching, learning and assessment. This framework strengthens students' professional skill training while aligning their abilities with industrial standards.

2.3. Five-dimensional competency evaluation model

Conventional evaluation methods lack systematic support and cannot fully reflect the development of students' comprehensive literacy under digital teaching environments [12]. To address this issue, an evaluation index system covering spatial reconstruction, construction analysis, standard application, teamwork and innovation capabilities is established for all-round assessment of students' comprehensive quality.

2.3.1. Definition of competency dimensions

The connotation of each competency dimension and corresponding teaching links are shown in **Table 1**.

Table 1. Five-dimensional competency evaluation

Competency Dimension	Connotation Definition	Corresponding Teaching Stage
Spatial Conversion Capability	Ability to convert between two-dimensional drawings and three-dimensional models	Cognition Stage
Construction Understanding Capability	Depth of cognition towards structural practices and construction procedures	Analysis Stage
Standard Application Capability	Practical proficiency in applying national standards correctly	Application Stage
Collaborative Operation Capability	Comprehensive literacy of teamwork and communication expression	Application Stage
Innovative Design Capability	Optimized thinking for complex problems	Expansion Stage

2.3.2. Collection of process data

A multi-source heterogeneous data fusion collection framework is proposed to improve the accuracy of the evaluation system [12]. The Learning Management System (LMS) records students' platform login frequency, resource browsing records, and task completion status; BIM software analyzes users' modeling operation tracks and error patterns; other interactive data, including team communication duration and file exchange frequency, are extracted from online collaboration platforms. Integrated data analysis generates visual charts of individual knowledge competency profiles and group performance distribution, providing a basis for designing differentiated teaching plans [13].

2.3.3. Application of evaluation results

The five-dimensional competency evaluation system delivers multiple values in educational practice: it generates personalized academic performance analysis reports and growth trend guidance for students, and helps teachers gain a holistic understanding of class learning conditions to optimize teaching approaches.

3. Empirical research

3.1. Experimental design

A quasi-experimental research design is adopted in this study, with 80 sophomores majoring in Architectural Engineering Technology (Class of 2024) from Chongqing Water Resources and Electric Engineering College as research subjects, divided into a control group and an experimental group with 40 students each. There is no statistically significant difference ($P > 0.05$) between the two groups in gender ratio, age structure and academic background, ensuring the reliability and scientific validity of research results. Stratified random sampling is adopted to guarantee sample representativeness and result validity.

The control group receives conventional teaching methods, while the experimental group adopts the innovative BIM+XR teaching system paired with five-dimensional competency evaluation. The research is jointly conducted by two professional teachers with rich teaching experience and relevant training certificates, over a complete 16-week semester. Curricula are systematically arranged centering on core components of civil buildings. At the end of the semester, both groups participate in unified standardized final examinations and comprehensive questionnaires.

3.2. Effect evaluation

3.2.1. Remarkable improvement in drawing reading ability

Research results indicate that students in the experimental group using AR-assisted technology achieve far faster drawing reading speeds than the control group. The average reading time drops from 18.3 minutes before intervention to 10.6 minutes after teaching, representing a 42% reduction. Students in the experimental group show obvious advantages in cognitive load management and conversion from two-dimensional views to three-dimensional entities.

3.2.2. Higher accuracy in drawing structural details

Statistical data show the average score of the experimental group reaches 87.2, compared with 64.5 for the control group, a gap of 22.7%. The perspective function of MR Mixed Reality technology delivers prominent advantages in analyzing complex structures and reduces risks of cognitive bias.

3.2.3. Significant decline in technology anxiety index

Although students in the experimental group encounter operational difficulties when using digital tools, their overall technology anxiety level drops by approximately 28% compared with initial measurements. The average score for perceived technical convenience reaches 4.21 (full score 5), and the recognition score for practical technical value stands at 4.47.

4. Implementation guarantee system

4.1. Teacher training path

Cultivating dual-qualified teachers with solid theoretical foundations and rich industrial experience is the key to promoting digital teaching modes [14]. First, a long-term school-enterprise collaborative education mechanism shall be established, with senior enterprise engineers employed as part-time lecturers to participate in textbook compilation and practical guidance together with college teachers. Second, enterprise expert workstations shall be set up to organize regular technical training and seminars. Third, outstanding teachers shall be selected for further study and relevant industrial vocational qualification examinations.

4.2. Development of teaching resources

Digital loose-leaf textbooks are compiled guided by the all-round education concept. Modular design is adopted for textbook writing, splitting core knowledge points into independent yet interconnected units. Digital resource packages are integrated into loose-leaf textbooks via QR codes for students' instant access and application. Textbook frameworks are continuously updated and adjusted in accordance with industrial standards, emerging technologies and new market demands to adapt to actual professional development needs.

4.3. Continuous improvement mechanism

A curriculum quality evaluation and improvement system is built based on the PDCA cycle theory [15]. The curriculum team systematically analyzes and assesses five-dimensional competency measurement data to explore students' core competency attainment, identify teaching deficiencies and formulate improvement strategies, forming a closed-loop operation mechanism.

5. Conclusion and prospect

5.1. Research conclusions

Targeting the existing problems of the course Architectural Structure and Drawing Recognition, this paper proposes a three-stage five-dimensional digital teaching model to enhance teaching quality. Research proves that the innovative teaching model effectively boosts students' learning efficiency, reduces cognitive burden and improves practical operation capabilities. The goal-oriented comprehensive evaluation system breaks the limitations of traditional single scoring methods to assess students' comprehensive literacy in an all-round manner.

5.2. Future research directions

Two directions are available for further expansion of this research. First, develop a teaching platform based on digital twin technology to build immersive environments integrating physical buildings and virtual spaces, establish a full-life-cycle knowledge system and optimize talent training models. Second, design a credit certification framework based on blockchain technology to convert students' BIM modeling achievements and VR training data into digital assets, promoting the standardization and authority of vocational education skill assessment for higher education degree conferral.

Funding

Research on Teaching Reform of the Higher Vocational Course Preparation and Implementation of Construction Organization from the Perspective of "Golden Courses" (Project No. Z2241544)

Disclosure statement

The authors declare no conflict of interest.

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