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Research on the Teaching Reform Path for the Intelligent Construction Major Based on the OBE Concept and Empowered by AI

Kai Zhao

Intelligent Construction College, Fuzhou University of International Studies and Trade, Fuzhou, Fujian, China
411308497@qq.com

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Abstract: With the rapid advancement of artificial intelligence (AI) technology and the swift rise of the intelligent construction industry, the architecture and construction sector is undergoing unprecedented transformation. In this context, cultivating high-quality intelligent construction professionals who can meet the demands of the new era has become a critical issue in higher education reform. Guided by the Outcome-Based Education (OBE) concept and empowered by AI technology, this paper proposes a closed-loop reform model that treats OBE as the framework and AI as the tool. It elaborates on the integrative logic of OBE and AI empowerment, and explores innovative pathways for teaching reform in intelligent construction education. These include restructuring the curriculum system, innovating teaching methods, enhancing practical training, and reforming evaluation mechanisms, thereby providing theoretical support and practical guidance for the pedagogical reform of intelligent construction programs.

1. Introduction

Over the past decade, the rapid development of digital technologies has profoundly reshaped traditional knowledge structures and disciplinary systems, significantly impacting conventional architecture and civil engineering disciplines. With remarkable advancements in artificial intelligence, algorithms, the Internet of Things, and robotics, the integration of cutting-edge technologies with traditional industries continues to deepen, driving the construction sector toward digitalization, networking, and intelligent transformation [1]. These industrial changes have, in turn, imposed higher requirements on talent cultivation in higher education institutions [2].

Under the guidance of China's 14th Five-Year Plan, as of May 2025, a total of 127 Chinese universities have established intelligent construction programs and related courses. These initiatives aim to build interdisciplinary knowledge systems by integrating expertise in mechanical design, electronic information, automation, and artificial intelligence, with the goal of cultivating comprehensive professionals. However, due to the relatively recent establishment of this discipline, many institutions face challenges such as limited teaching content, insufficient interdisciplinary integration, outdated software and hardware equipment, lagging curricula, and a disconnect between theory and practice [3]. Moreover, traditional teaching models struggle to meet the comprehensive and innovative talent demands of the intelligent construction industry. Against this backdrop, the Outcome-Based Education (OBE) concept has emerged as a significant direction for educational reform. Emphasizing student-centeredness and results-oriented approaches, OBE focuses not only on knowledge acquisition but also on cultivating practical application capabilities. The OBE concept was first proposed by American scholar Spady W.G. in 1981 and refined in 1994 [4]. It gradually developed in the 1980s and 1990s and has been promoted and applied globally. It has now become the mainstream concept of educational reform in countries such as the United States, the United Kingdom, and Canada. It has been fully adopted by the engineering education professional accreditation. Applying OBE to guide engineering education reform in China has practical significance for promoting specialized program development, teaching innovation, and enhancing the quality of talent training.

Furthermore, in the wave of digital transformation, artificial intelligence (AI) is profoundly reshaping various fields, including education. The World Economic Forum’s 2024 report, Shaping the Future of Learning: The Role of AI in Education 4.0, systematically explores how AI is facilitating the global transition to an “Education 4.0”system.The report emphasizes a learner-centered intelligent education framework, advocating for the redesign of learning content and experiences to meet the future societal demand for interdisciplinary talent [5]. In parallel, since 2023, China has been regularly publishing the Annual Report on AI in Education, which aims to track the implementation and effectiveness of AI education policies and evaluate intelligent education through quantitative indicators. AI-enabled education not only introduces innovative approaches to teaching models but also offers new possibilities for personalized and intelligent education. The widespread application of AI technologies provides renewed technical support for pedagogical reform. Therefore, exploring the integration of OBE and AI in the teaching reform of intelligent construction programs carries significant theoretical and practical importance.

2. The Latest Application Trend of OBE Concept and AI enabling Education and Teaching

2.1 The Core Connotation of OBE concept

OBE (Outcome-Based Education) emphasizes student-centered learning outcomes, representing an educational philosophy focused on achieving measurable results. The ultimate learning outcome (peak achievement) serves as both the endpoint and starting point of OBE. Traditional education, however, follows a subject-oriented approach that tends to address specific, linear, and closed-ended scientific problems. Its knowledge structure prioritizes systematic completeness within disciplinary frameworks, with instructional design focusing more on academic requirements while neglecting practical employment needs [6]. In contrast, OBE adheres to reverse design principles, emphasizing what students learn rather than what teachers teach, and prioritizing output over input in the teaching process. At its core, it involves designing curricula through backward planning, building teaching content and assessment systems based on learning outcomes to ensure students develop practical problem-solving skills.

The application of the Outcomes-Based Education (OBE) philosophy in engineering education plays a vital role in enhancing educational quality, meeting industry demands, and fostering students 'holistic development. While OBE has achieved partial success in engineering education—such as through results-oriented modular teaching, project-driven approaches, and diversified assessments that improve students' practical skills and innovative thinking—the implementation still faces challenges including teachers 'role transformation, cultivating students' self-directed learning abilities, and aligning with industry needs [7].

2.2 Application Trend of AI Technology Enabling Education and Teaching

With the advent of ChatGPT and the rapid advancement of AI technology, an increasing number of application fields are being impacted by AI. The integration of AI undoubtedly opens up new possibilities for educational reform. AI can be applied to personalized learning path planning, intelligent teaching resource recommendations, and learning behavior analysis, thereby enhancing teaching efficiency and learning outcomes. The latest technological trends empowering education through AI primarily include the following aspects:

(1) Intelligent Teaching System: AI-powered educational solutions, including intelligent tutoring systems and adaptive learning platforms, provide personalized learning paths and real-time feedback to help students master knowledge effectively. These systems tailor learning plans based on students 'academic behaviors and cognitive patterns. intelligent teaching assistants automatically grade assignments and provide exam feedback, reducing teachers' workload and allowing them to focus on instruction. Additionally, these AI-powered tools offer 24/7 online support for student inquiries, deliver precise learning guidance, and automatically adjust content difficulty according to students' progress through adaptive learning platforms. This approach enhances learning efficiency and achieves personalized education tailored to individual needs.

(2) Big Data Analysis: By integrating big data technology, AI can conduct in-depth analysis of students 'learning behaviors, interests, and capabilities. This enables optimized teaching content and assessment methods, thereby enhancing instructional efficiency and learning outcomes. In contemporary education, the integration of deep learning with big data has become a significant trend. Through collecting massive learning data, AI systems can analyze learners' behaviors in depth, identify learning difficulties, and propose targeted solutions. This data-driven approach not only improves educational effectiveness but also provides scientific foundations for decision-making. For instance, through natural language processing technology, AI can intelligently generate course content, teaching materials, and even exam questions, offering educators robust support.

(3) Virtual Simulation and Immersive Learning: The integration of Virtual Reality (VR) and Augmented Reality (AR) technologies with Artificial Intelligence (AI) creates immersive learning environments where students can practice operations in virtual settings. This "intelligent immersive learning" not only enhances students 'intuitive understanding and engagement but also provides a safe and efficient solution for high-cost, high-risk, or impractical experiments and training. Institutions like Stanford University School of Medicine and Johns Hopkins University utilize AI-integrated VR surgical simulators to train both students and surgeons. Students wear VR headsets to perform surgeries in highly realistic virtual human models, including dissection, suturing, joint replacement, and even complex cardiac procedures. Engineering students at MIT and Germany's RWTH Aachen University use AR glasses like Microsoft HoloLens when learning complex mechanical equipment assembly or production line maintenance. Virtual 3D models, operational instructions, and animations are directly overlaid onto real physical devices or teaching models, transforming abstract theoretical knowledge into visualized, hands-on guidance that helps students familiarize themselves with advanced work methods in the Industry 4.0 era.

(4) Educational equity and resource sharing: AI technology, through online platforms and intelligent tools, breaks the restrictions of region and resources, enables more students to have access to high-quality educational resources, reduces the educational gap between urban and rural areas, regions and rich and poor, and promotes educational equity.

2.3 The integration logic of OBE concept and AI empowerment

In traditional OBE models, curriculum revisions typically follow 3-5 year cycles, which significantly lags behind the accelerated technological iteration in fields like intelligent construction (now occurring every 6-12 months) [8]. This periodic lag often causes teaching content to become disconnected from industry demands, failing to reflect technological advancements and evolving industrial needs. The integration of AI technology offers new possibilities for dynamic OBE updates. This paper proposes a closed-loop reform model that uses OBE as the framework and AI as the tool, shifting focus from "time-oriented" to "capability-oriented" approaches. By breaking curriculum cycle constraints, resolving the contradiction between static objectives and dynamic industrial demands, and leveraging AI feedback for real-time content adjustments, we establish an adaptive continuous improvement mechanism. This effectively achieves dynamic teaching optimization, as illustrated in Figure 1.

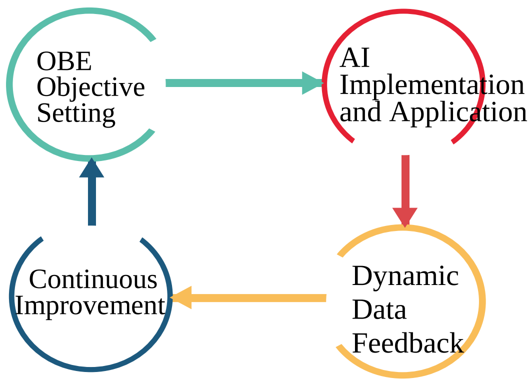

Figure 1: OBE-AI closed-loop model

Based on this OBE-AI closed-loop model, the teaching system logic diagram of AI enabling OBE concept is shown in Figure 2.

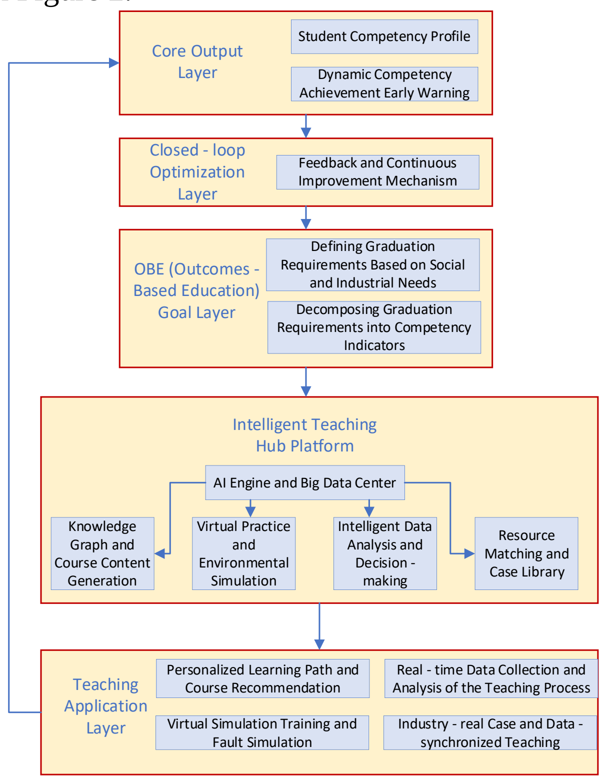

Figure 2: Teaching system logic diagram of AI enabling OBE concept

This logical diagram systematically establishes a new paradigm for intelligent construction education, centered on data-driven approaches, powered by AI technology, and guided by OBE outcomes. Its core logic lies in creating a closed-loop, self-optimizing intelligent education ecosystem through top-down goal decomposition and bottom-up data empowerment.

First, the system's top-level framework anchors the OBE philosophy, establishing "social and industrial needs" as the fundamental starting point for defining final graduation requirements. This signifies that the curriculum system originates not from traditional textbooks or syllabi, but rather from the practical competency demands of the intelligent construction industry during its digital and intelligent transformation (such as BIM collaborative management, intelligent construction decision-making, and building energy optimization). These overarching "graduation requirements" are further broken down into quantifiable and assessable "competency indicators", providing clear targets for all subsequent teaching activities and evaluations.

Subsequently, AI technology, as the central nerve, permeates and reshapes the whole teaching process, which is embodied in four core enabling modules:

(1) Knowledge Graph and Course Generation: By leveraging Natural Language Processing (NLP) and knowledge graph technologies, the system dynamically constructs interdisciplinary knowledge networks spanning civil engineering, computer science, and management. Through real-time analysis of emerging industry trends and competency gaps, it intelligently recommends or generates modular course content (such as "BIM + IoT" integrated courses), effectively addressing the challenges of rigid curriculum structures and insufficient interdisciplinary integration.

(2) Virtual Practice and Environmental Simulation: Leveraging VR/AR and digital twin technologies, we create high-fidelity, highly interactive virtual environments for intelligent construction sites. Students can conduct high-risk, high-cost operational training (such as safety fault simulations in deep excavations and coordinated scheduling of large equipment) within these environments, while receiving real-time guidance and feedback from embedded AI agents. This approach effectively addresses the challenge of lacking practical teaching scenarios in traditional education.

(3) Data Intelligence Analysis and Decision-Making: This constitutes the core of the system's data processing framework. By employing multimodal learning analytics technology, it continuously captures behavioral, verbal, and textual data generated during virtual training sessions, project collaborations, and classroom interactions. Through in-depth data mining and modeling, the system provides objective evidence for implementing process-oriented evaluation systems.

(4) Resource Matching and Case Library: By leveraging cloud computing and IoT technologies, we establish a cloud-based collaboration platform that seamlessly integrates real-time industry-sensitive data streams and engineering case libraries (including live project progress and material cost data). This ensures that educational resources evolve in sync with technological advancements, effectively overcoming the bottleneck where teaching equipment and resources lag behind industrial development.

In the instructional application layer, these AI capabilities are implemented through concrete teaching scenarios: personalized learning path planning, immersive simulation training, real-time data collection and analysis of teaching processes, and synchronized instruction using authentic industry cases. This layer directly demonstrates AI's empowerment in education, transforming traditional "teacher-centered lectures" into a student-led, AI-assisted, data-driven personalized learning experience.

Ultimately, the system outputs core achievements and forms a closed-loop system. All teaching process data converges into a dynamic "student competency profile," enabling precise characterization and visual presentation of each student's competency attainment while providing early warnings for potential gaps. These evaluation results are not endpoints but serve as critical inputs for the "feedback and continuous improvement mechanism." They feed back into the setting of curriculum objectives and graduation requirements, offering quantitative decision support for optimizing professional training programs and reforming teaching methodologies. This truly completes the OBE "evaluation-feedback-improvement" cycle, achieving sustained enhancement of educational quality.

3. The Implementation Path of OBE Concept and AI Enabling in the Teaching Reform Program of Intelligent Construction

3.1 Restructuring of Competency Objectives: Define the Talent Portrait of "New Engineering" based on Industry Needs and AI Capabilities

The starting point of OBE is to define clear and measurable learning outcomes. We first need to restructure competency objectives and answer the fundamental question of "what kind of people are we cultivating".

(1) To achieve talent development objectives, we implement "reverse design and demand-driven" strategies by establishing a Professional Development Committee comprising corporate technical directors, industry experts, and veteran educators. This committee conducts in-depth analysis of competency requirements across industrial chain segments including intelligent design, intelligent construction, and AI-powered operation and maintenance (O&M). Particular emphasis is placed on identifying emerging skills demanded by AI application scenarios – such as BIM model verification systems, automated construction progress optimization, and roboticized building operations – which will profoundly shape future talent cultivation needs.

(2) Establish a three-dimensional objective system of "knowledge, competence, and quality". From the knowledge dimension: consolidate civil engineering fundamentals while enhancing expertise in digital technologies such as artificial intelligence, data science, IoT, and BIM; From the competence dimension: emphasize AI application capabilities (using AI tools to solve engineering problems), interdisciplinary integration skills (combining knowledge from civil engineering, mechanical engineering, and information technology), complex engineering problem-solving abilities, and innovative thinking; From the quality dimension: cultivate digital literacy, ethical responsibility awareness, teamwork capabilities, and lifelong learning capacity.

(3) The graduation requirements are decomposed into each course and each teaching module in the curriculum system, forming a support relationship matrix to ensure that the ability cultivation is continuous.

3.2 Curriculum System Reconstruction: Break the Disciplinary Barriers and Build a "Intelligent +" Modular Curriculum Group

Guided by the OBE philosophy, the curriculum system for intelligent construction should prioritize student competency development while emphasizing the integration of theory and practice. The course content should align with industry demands in this field, incorporating cutting-edge technologies such as AI, big data, and IoT to establish an interdisciplinary "Intelligent+" modular curriculum framework.

(1) We will establish the core curriculum group for "Intelligent Construction," introducing foundational courses such as "Introduction to Intelligent Construction," "BIM Technology and Application," "Artificial Intelligence in Architecture," "Python and Building Data Analysis," and "Intelligent Machinery and Robotics" as the cornerstone of the major.

(2) We are advancing the bidirectional integration of "Civil Engineering+" and "AI+" technologies. This fusion is not merely adding superficial elements to traditional civil engineering

curricula, but rather achieving deep integration. For instance: The course "Principles of Concrete Structural Design" incorporates machine learning-based concrete strength prediction and mix design optimization; "Construction Organization Design" integrates evolutionary algorithm-based multi-objective scheduling optimization for construction resources. Additionally, intelligent teaching assistants provide real-time Q&A support, while adaptive learning platforms deliver personalized resources.

(3) Building upon core professional courses, the program offers modular curricula including specialized electives and industry-specific modules. Students can customize their learning paths based on career aspirations and interests, enhancing curriculum flexibility. Each module employs project-based instruction where learners tackle real-world or simulated challenges, effectively developing hands-on expertise in intelligent construction technologies.

3.3 Innovation of Teaching Methods: Student-centered, AI-enabled personalized and inquiry-based learning

Teaching methodologies are pivotal to achieving competency objectives. The Outcomes-Based Education (OBE) philosophy emphasizes student-centered approaches, advocating diverse instructional methods such as project-based learning, case studies, and flipped classrooms. AI technology offers boundless possibilities for pedagogical innovation. In intelligent construction education, instructors should fully utilize modern educational technologies like virtual simulations and AI-assisted tools to enhance interactive engagement and personalized learning experiences.

(1) AI-powered personalized learning path recommendations: By leveraging learning analytics technology, we create detailed digital profiles of students. The AI system dynamically suggests tailored learning resources and practice exercises based on their behavioral data (such as video viewing duration, homework accuracy rate, and forum engagement), enabling "teaching tailored to individual needs".

(2) Project-Based Learning (PBL) and Virtual Simulation: Bringing real-world corporate projects into classrooms. By integrating BIM, VR/AR, and digital twin technologies, we create highly realistic virtual construction sites. Students work in teams to complete full lifecycle projects—from design and construction to management—in this virtual environment. AI systems simulate various unexpected scenarios like weather changes and equipment failures. Through collaborative problem-solving and project presentations, students enhance their practical skills, teamwork capabilities, and emergency decision-making abilities.

(3) A human-machine collaborative intelligent mentor system: Develop or introduce AI teaching assistants that can answer students 'routine questions 24/7, provide code debugging suggestions, and conduct preliminary automated compliance checks and optimization recommendations on students' design outcomes. This system liberates teachers from repetitive tasks, allowing them to focus more on heuristic and challenging instruction.

3.4 Strengthening Practical Teaching: Build an Integrated Practice Platform of "Combining Virtual and Real, Industry, Education, Research and Application"

The OBE concept emphasizes the importance of practical teaching. The intelligent construction major should strengthen the practical teaching link and break the boundary between laboratory and construction site.

(1) Building an "intelligent construction Innovation Center": The center should integrate hardware such as UAV, 3D printer, construction robot, various sensors and edge computing equipment, as well as software such as BIM software, AI development platform and digital twin system, to form a complete closed-loop experimental environment of "data collection, transmission,

analysis, decision-making and execution".

(2) Implementing the "Enterprise Real-Project into Classroom" Initiative: Partnering with leading construction and technology companies to establish dual mentorship systems, we co-create industry-academia practice bases. By transforming real-world technical challenges (such as "AI-powered precision calculation of construction material consumption") into student innovation projects, we equip learners with practical problem-solving skills through authentic environments. The outcomes carry substantial real-world value.

3.5 Evaluation System Reform: Based on Data-driven, Achieve Whole-process, Multi-dimensional and Value-added Evaluation

The closed-loop of OBE is reflected in continuous improvement, and the basis of improvement comes from a scientific and reasonable evaluation system. Under the concept of OBE, the evaluation system should be oriented to learning outcomes, focusing on the combination of process evaluation and result evaluation.

(1) The evaluation content is diversified: from a single knowledge assessment to a comprehensive evaluation of abilities, literacy and achievements. The focus is on evaluating students' performance in the project, innovative thinking, proficiency in the use of AI tools, and team contribution.

(2) Process and data evaluation: Learning management system (LMS) and AI analysis tools are used to collect learning data in the whole process without awareness, such as code submission times, model iteration versions, online discussion quality, virtual simulation operation records, etc., and form process evaluation reports.

(3) Multiple evaluation subjects: Enterprise mentor evaluation, peer evaluation and AI system automatic evaluation (such as code quality assessment and model performance scoring) are introduced to form a multi-dimensional evaluation subject combined with teacher evaluation.

(4) Emphasize "value-added" evaluation: Focus on the growth of students' abilities from enrollment to graduation, rather than just focusing on the final results. Through the comparison of before and after tests, evaluate the actual effect of teaching activities, and provide accurate basis for continuous improvement.

4. Conclusions and Outlook

The intelligent construction education reform, rooted in OBE principles and AI empowerment, constitutes a systematic endeavor. It begins with defining future talents' competencies precisely and culminates in reshaping the entire educational ecosystem encompassing curriculum design, teaching methodologies, practical training, and assessment systems. AI serves as both an enabler and catalyst, enabling personalized education at scale, immersive hands-on experiences, and data-driven precision evaluation. However, the success of this reform hinges on three critical factors: enhancing faculty capabilities, deepening industry-academia collaboration, and implementing supportive institutional policies. Moving forward, we must proactively drive innovation by further integrating OBE frameworks with AI technologies, ultimately cultivating exceptional engineers and innovators who will lead transformative changes in the construction industry.

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