Chapter 8
AI-Powered VR/AR Environments for Experiential Civil Engineering Education

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ABSTRACT

This paper explored the transformative role of Artificial Intelligence (AI) and immersive technologies Virtual Reality (VR), Augmented Reality (AR), and Extended Reality (XR) in civil engineering and education. In engineering site development, immersive technologies are increasingly used for safety simulations and virtual walkthroughs, allowing engineers to detect and resolve issues before construction

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begins. Given the complexity and urgency of civil engineering projects, AR and VR simulations enable engineers to test scenarios and refine repair strategies with precision. The paper also addresses challenges in implementing VR/AR, such as hardware requirements, training, and data management. Its central aim is to boost occupational efficiency and responsiveness in civil engineering education through a gamified Actor-Network Theory (ANT) model supported by the Technological Pedagogical Content Knowledge (TPACK) framework. An adaptive federated cloud learning system was developed to examine AR/VR integration in civil engineering education and practice.

1. INTRODUCTION

Educational technology has evolved methodologically, transitioning from conventional teaching approaches to simulation-driven technologies that emphasize real-world experiences, fostering deeper understanding and practical skill development across disciplines, and reshaping how learners engage with content, and technology-oriented environments(Ugochukwu Okwudili Matthew, Kazaure, Kazaure, Hassan, et al., 2022). Through immersive instructional strategies, educators and industry professionals can now tailor learning experiences to individual needs by leveraging video game development tools such as virtual reality (VR), augmented reality(AR), and extended reality(XR) to foster collaborative engagement(Yadav, 2025). These technologies facilitate real-time communication, shared problem-solving, and experiential learning by simulating realistic scenarios and enhancing user presence. By integrating these tools into educational profession, individuals can work together more effectively, build stronger connections, and achieve common goals through dynamic, visually rich, and participatory experiences. To strengthen the Technological Pedagogical Content Knowledge (TPACK) framework, this study introduces artificial intelligence (AI)-integrated, cloud-adaptive learning environments enriched with VR and AR gamification, structured through the Actor-Network Theory (ANT) model. The research explores the pedagogical potential of immersive technologies in civil engineering education, demonstrating their capacity to revolutionize training in structural engineering. By examining the educational advantages, implementation challenges, and future opportunities of VR and AR, the study underscores their growing relevance and transformative impact within the field. In the end, the TPACK framework serves as a foundation for integrating XR and AI tools to enhance teaching practices, improve learning outcomes, and better equip graduates for the evolving demands of civil engineering careers. The rapid evolution of digital technologies ushered a transformative era for architecture and construction, where immersive environments and intelligent systems are redefin-