"Augmented Reality-Driven STEM-PjBL: Transforming Critical Thinking in Science Education"

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Abstract

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The integration of Augmented Reality (AR) into education offers a promising avenue for enhancing critical thinking, yet empirical evidence on its effectiveness particularly within structured pedagogical models—remains limited. This study investigates the impact of AR-assisted Project-Based Learning (PjBL) integrated with STEM (Science, Technology, Engineering, and Mathematics) education on eighth-grade students' critical thinking skills in science learning. Addressing the urgent need for innovative teaching strategies that bridge theoretical knowledge and real-world application, this research employs a quantitative experimental design with two groups: an experimental group using AR-based PjBL-STEM and a control group taught through conventional methods. Pre- and post-tests, complemented by structured observations, were used to assess critical thinking development. Results revealed that students in the experimental group exhibited significantly greater gains in critical thinking compared to the control group. The AR-based PjBL-STEM approach fostered deeper engagement with scientific content, improved problem-solving abilities, and enhanced the transfer of concepts to authentic contexts. These findings underscore the novelty of combining AR with PjBL-STEM as an integrated model that not only enriches learning experiences but also addresses persistent challenges in cultivating higher-order thinking skills in science education. This study contributes to the growing body of knowledge on technology-enhanced pedagogy by providing empirical evidence of AR's potential in structured STEM learning environments. It offers practical insights for educators and policymakers seeking scalable, impactful solutions to promote critical thinking. Future research should examine longitudinal effects and broader applications of AR-based PjBL-STEM across diverse educational settings.

Keywords: Augmented Reality, Critical Thinking, Project-Based Learning, STEM, Science Education.

INTRODUCTION

Science education, particularly in the fields of mathematics and natural sciences, plays a crucial role in shaping students' critical thinking skills (Muttaqiin, 2023). In the 21st century, the ability to think critically is essential in facing various challenges and rapid global changes. Critical thinking skills are not only related to problem-solving abilities but also to the capacity to analyze, evaluate, and make decisions based on available information. In the context of science education, the development of these skills is vital as it affects not only learning outcomes but also students' readiness to participate in an increasingly complex and technology-driven society (R et al., 2023).