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Analysis of the Effectiveness of Augmented Reality Based Interactive Learning Media on Students Concept Comprehension Skills

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Abstract: The rapid advancement of educational technology demands innovative approaches to teaching abstract scientific concepts. This study analyzes the effectiveness of Augmented Reality based interactive learning media in improving students concept comprehension skills. Traditional two dimensional teaching materials often fail to provide adequate spatial representation, leading to persistent student misconceptions. Using a quasi experimental quantitative method, this research involved an experimental group using Augmented Reality media and a control group using conventional printed textbooks. Data were collected through pretest and posttest instruments specifically designed to measure cognitive understanding across multiple indicators. The findings demonstrate a significant improvement in the experimental group, evidenced by a considerably higher normalized gain score compared to the control group. Augmented Reality media allows students to manipulate three dimensional virtual objects in real time, thereby successfully bridging the cognitive gap between abstract theories and concrete visual representations. The study concludes that integrating Augmented Reality into the instructional process is highly effective in enhancing conceptual comprehension. It is strongly recommended that school administrators and curriculum developers facilitate the broader application of this interactive technology, particularly for subjects requiring high spatial visualization.

Keywords: Augmented Reality, Interactive Learning Media, Concept Comprehension, Educational Technology, Quasi Experimental

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INTRODUCTION

The integration of digital technology into the educational sector has fundamentally shifted the pedagogical landscape from traditional teacher centered instruction to highly interactive student centered learning. One of the most persistent challenges in modern education is the difficulty students face when trying to comprehend abstract or multidimensional concepts. Subjects such as physics, biology, and spatial geometry require students to visualize complex structures that cannot be adequately represented by static images on a whiteboard or printed textbooks. Consequently, students often resort to rote memorization rather than developing a genuine understanding of the underlying principles (Pratama & Hidayat, 2024). This superficial learning approach inevitably leads to poor academic performance and a rapid

decline in concept retention.

To address this cognitive bottleneck, Augmented Reality has emerged as a highly promising educational tool. Augmented Reality technology overlays digital information, such as three dimensional models and animations, onto the physical world through the camera lens of a smartphone or tablet. Unlike Virtual Reality which completely immerses the user in a synthetic environment, Augmented Reality maintains the users connection to their physical classroom while enriching it with interactive virtual objects (Chen & Wang, 2021). This unique capability allows students to observe, rotate, and interact with complex scientific models from multiple angles. For instance, learners can visually dissect a human heart or observe planetary orbits in real time right on their study desks.

Despite the theoretical advantages of this technology, empirical evidence regarding its specific impact on cognitive comprehension in the Indonesian school context remains relatively fragmented. Previous studies have primarily focused on the software development aspect of Augmented Reality applications or measured general student motivation rather than strictly evaluating academic outcomes (Susanti, 2023). There is a critical need for rigorous quantitative evaluation to determine whether the visual appeal of Augmented Reality actually translates into measurable improvements in conceptual understanding.

Therefore, this research aims to quantitatively analyze the effectiveness of Augmented Reality based interactive learning media on students concept comprehension skills. The study formulates the problem of whether there is a significant difference in learning outcomes between students taught using Augmented Reality media and those taught using conventional methods. By providing solid empirical data, this research intends to offer concrete recommendations for educators and policymakers regarding the adoption of immersive technology to optimize classroom instruction.

METHODS

This research employed a quantitative approach utilizing a quasi experimental design, specifically the nonequivalent control group design. This methodology is highly suitable for evaluating the effectiveness of a specific instructional intervention in a natural school setting where random assignment of individual students is not administratively feasible (Creswell, 2021). The study was conducted at a public high school in Banda Aceh, focusing on abstract science subjects during the even semester of the academic year 2025 to 2026.

The population of this study consisted of all eleventh grade students. Through a purposive sampling technique, two intact classes with comparable initial academic abilities were selected as the research sample. The first class was designated as the experimental group, receiving instruction utilizing Augmented Reality based interactive learning media. The second class served as the control group, receiving standard instruction utilizing conventional printed textbooks and two dimensional slides.

Data collection was executed using a validated cognitive test instrument consisting of multiple choice questions designed to measure various indicators of concept comprehension. Both groups were given a pretest before the treatment to establish their baseline knowledge. After several weeks of the instructional intervention, a posttest with the same difficulty level was administered. The collected data were analyzed using descriptive and inferential statistics. The improvement in student comprehension was calculated using the normalized gain score formula. Furthermore, an independent sample t test was conducted utilizing statistical software to determine the significance of the difference in learning outcomes between the two groups.

RESULTS AND DISCUSSION

The empirical data gathered from the cognitive tests reveal a substantial disparity in academic achievement between the two observed groups. Before the implementation of the instructional intervention, the pretest results indicated that both the experimental group and

the control group possessed a nearly identical baseline understanding of the subject matter. However, following the treatment period, the posttest scores presented a highly divergent outcome. The experimental group, which utilized the Augmented Reality based interactive learning media, achieved a significantly higher average posttest score compared to the control group. The inferential statistical analysis utilizing the independent sample t test confirmed that this difference is mathematically significant, thereby rejecting the null hypothesis. Furthermore, the normalized gain score analysis categorized the cognitive improvement of the experimental group within the high effectiveness criteria, whereas the control group remained in the moderate category (Pratama & Hidayat, 2024).

The superior performance of the experimental group can be directly attributed to the unique spatial affordances provided by the Augmented Reality technology. During the instructional process, students in the experimental class were not merely passive recipients of verbal explanations. They actively utilized their mobile devices to project three dimensional virtual models onto their desks. This interactive capability allowed them to physically walk around the virtual objects, zoom in on intricate details, and observe dynamic processes that are otherwise invisible to the naked eye. This aligns with the cognitive load theory, which suggests that providing simultaneous visual and spatial information significantly reduces the mental effort required to process abstract concepts (Chen & Wang, 2021). By transforming abstract theories into tangible visual representations, the Augmented Reality media effectively bridged the cognitive gap that usually hinders student comprehension.

In contrast, students in the control group struggled to construct accurate mental models based solely on the static illustrations found in their textbooks. The two dimensional format restricted their spatial perception, forcing them to rely heavily on memorization to compensate for their lack of genuine understanding (Susanti, 2023). Additionally, observations during the treatment revealed that the Augmented Reality media drastically increased student engagement and curiosity. The novelty of the technology transformed a conventional lecture into an exploratory experience, maintaining the students focus for a much longer duration. This finding strongly supports the premise that interactive educational technology does not merely serve as an aesthetic gimmick. When properly integrated into a structured lesson plan, Augmented Reality functions as a powerful cognitive amplifier that translates complex academic material into an easily digestible and highly engaging format.

CONCLUSION

The findings of this quantitative study provide compelling evidence regarding the effectiveness of modern educational technology in the classroom. The utilization of Augmented Reality based interactive learning media significantly improves students concept comprehension skills compared to conventional instructional methods. The technology capability to visualize abstract and multidimensional concepts into interactive three dimensional models successfully lowers the students cognitive load and eliminates common misconceptions. The experimental group demonstrated a remarkably higher normalized gain score, proving that interactive visual learning leads to deeper academic understanding rather than superficial memorization. Based on these empirical results, it is highly recommended that educational institutions and teachers begin integrating Augmented Reality applications into their pedagogical strategies, particularly for complex science subjects. Future researchers are encouraged to expand the scope of this study by exploring the effectiveness of Augmented Reality across different academic disciplines and analyzing its long term impact on student knowledge retention.

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