

The Effectiveness of Augmented Reality Diorama in Improving Critical Thinking and Learning Motivation of Elementary School Students on Solar System Material

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Abstract: This study aims to analyze the effectiveness of the use of augmented reality (AR)-based diorama media on solar system material in improving elementary school students' critical thinking skills and learning motivation. The problem in this study is the low level of students' critical thinking skills and learning motivation due to learning that is still abstract, less interactive, and unable to visualize concepts concretely. This study employed a quantitative approach with a quasi-experimental design (nonequivalent control group design). The research sample consisted of 60 students, including 30 students in the experimental group and 30 students in the control group. Data collection techniques used a critical thinking skills test and a learning motivation questionnaire that had been tested for validity and reliability. Data analysis was conducted using an independent samples t-test. The results showed that there was a significant difference between the experimental group and the control group in terms of critical thinking skills and learning motivation ($p < 0.05$). The experimental group showed higher mean scores compared to the control group, indicating that the use of AR-based diorama media had a significant positive effect. These findings indicate the novelty in integrating augmented reality technology with diorama media to visualize abstract concepts more concretely. Therefore, AR-based diorama media can be an innovative, interactive, and contextual learning alternative in improving students' critical thinking skills and learning motivation in science learning at the elementary school level.

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Introduction

Science learning, particularly on solar system material, has characteristics of abstract concepts that cannot be directly observed by students. This condition often causes difficulties in understanding concepts, which has an impact on the low level of students' critical thinking

skills and learning motivation. From the perspective of constructivist theory, effective learning emphasizes the active involvement of students in constructing knowledge through direct experience and interaction with the learning environment. Meanwhile, multimedia learning theory states that concept understanding will be more optimal when information is presented through a meaningful integration of visual and verbal representations.

However, classroom learning practices still tend to be conventional, with the dominance of lecture methods and the use of less interactive media. This condition causes students to have difficulty visualizing abstract concepts such as the solar system, which ultimately results in low learning engagement and underdeveloped critical thinking skills. Therefore, innovative learning media are needed to provide more concrete, interactive, and contextual learning experiences.

One of the emerging innovations is the use of augmented reality (AR) technology. AR enables the integration of real and virtual objects, thereby providing more concrete and interactive visualizations (Azuma, 2020). Previous studies have shown that the use of AR in learning can significantly improve concept understanding and student engagement (Ibáñez & Delgado-Kloos, 2020). In addition, a study by Garzón and Acevedo (2021) revealed that AR technology has great potential in enhancing the quality of technology-based learning.

Nevertheless, previous studies still have several limitations that indicate the existence of a research gap. First, most studies still focus on the use of digital media separately without integrating physical media as a means of concrete learning, so that students' learning experiences are not yet fully multimodal. Second, studies examining the relationship between critical thinking skills and learning motivation simultaneously are still limited, even though both aspects are important indicators of success in 21st-century learning. Third, the implementation of AR technology in solar system materials at the elementary school level has not been widely studied specifically in the context of learning that combines visual and manipulative experiences simultaneously.

Urgency of this study lies in the need to present learning innovations that not only visualize abstract concepts concretely but also simultaneously develop students' critical thinking skills and learning motivation. Without appropriate innovation, science learning has the potential to remain passive and less meaningful for students.

Therefore, the novelty of this study lies in the development and use of augmented reality-based diorama media that integrates concrete visualization (physical diorama) with interactive technology (AR). In addition, this study examines the effectiveness of the media on two variables simultaneously, namely critical thinking skills and learning motivation of elementary school students, thereby providing a more comprehensive contribution compared to previous studies.

Based on the above description, the research question in this study is: is the use of augmented reality-based diorama effective in improving students' critical thinking skills and learning motivation on the topic of the solar system? The objective of this study is to analyze the effectiveness of using augmented reality-based diorama media in improving critical thinking skills and learning motivation of elementary school students.

Research Method

This study used a quantitative approach with a quasi-experimental design, specifically the Nonequivalent Control Group Design. This design was used to compare the differences in outcomes between the experimental group that received treatment in the form of augmented reality (AR)-based diorama media and the control group that used conventional learning.

The population in this study consisted of all sixth-grade elementary school students in Semarang City. The sample of the study consisted of 60 students, including 30 students in the experimental group and 30 students in the control group. The sampling technique used purposive sampling, with the following criteria: (1) students were at the same grade level, (2) had relatively equivalent academic characteristics based on previous scores, and (3) came from schools with comparable learning facilities. The selection of this technique aimed to minimize bias in initial ability differences between groups.

The variables in this study consisted of independent and dependent variables. The independent variable was the use of AR-based diorama media, while the dependent variables included students' critical thinking skills and learning motivation. Critical thinking skills were measured based on the indicators of: (1) interpretation, (2) analysis, (3) evaluation, (4) inference, and (5) explanation. Meanwhile, learning motivation was measured based on the dimensions of: (1) attention, (2) relevance, (3) confidence, and (4) satisfaction.

Data collection techniques were conducted through tests and questionnaires. The test instrument was used to measure students' critical thinking skills, while the questionnaire was used to measure learning motivation. Before being used, both instruments had undergone validity and reliability testing. The test results showed that the test instrument had a reliability coefficient of 0.82 and the learning motivation questionnaire had a reliability coefficient of 0.85, so both were declared reliable and appropriate for use in this study.

The research procedure was carried out over four meetings on the topic of the solar system. The stages of the study included: (1) administering a pretest to both groups to determine initial ability, (2) providing treatment to the experimental group using AR-based diorama media, while the control group used lecture methods and textbooks, (3) conducting the learning process over four meetings, and (4) administering a posttest to measure the improvement of critical thinking skills and distributing questionnaires to measure students' learning motivation.

Data analysis was carried out through several stages, namely the normality test to determine data distribution, the homogeneity test to ensure the equality of variances between groups, and hypothesis testing using the independent samples t-test. The test was conducted at a significance level of 0.05 to determine whether there was a significant difference between the experimental group and the control group.

The research flow diagram is presented in Figure 1, which shows the stages of the study starting from the administration of the pretest in the experimental and control groups, followed by the provision of treatment using augmented reality-based diorama media in the experimental group and conventional learning in the control group, the implementation of the learning process over four meetings, and the administration of the posttest and learning motivation

questionnaire. The obtained data were then analyzed using normality, homogeneity, and hypothesis testing with the independent samples t-test.

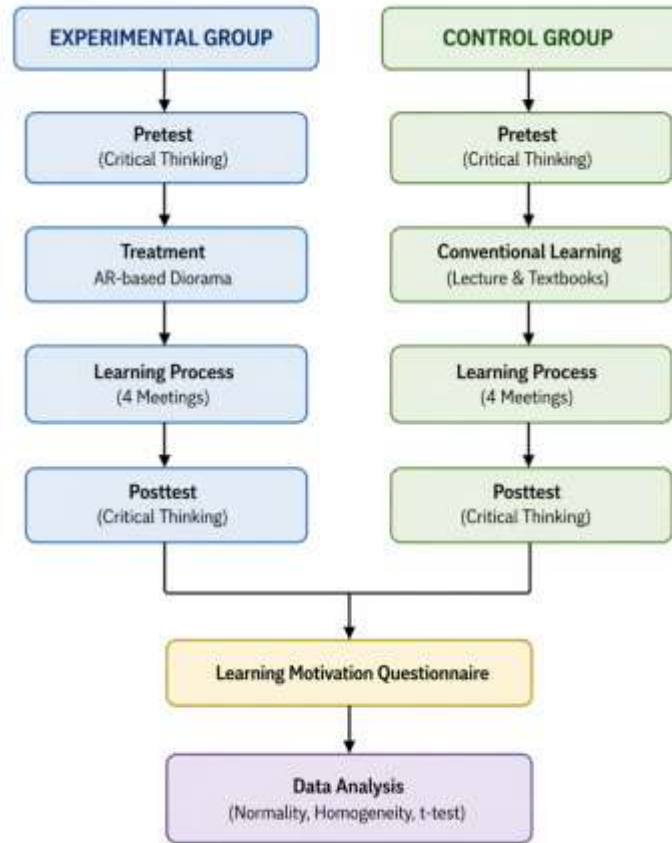


Figure 1. The Research Flow

Result and Discussion

Research Results

This study aims to determine the differences in students' critical thinking skills and learning motivation between the group using augmented reality-based diorama media and the group using conventional learning. The research results are presented based on two main variables, namely critical thinking skills and learning motivation.

1. Critical Thinking Skills

To determine the differences in students' critical thinking skills between the experimental group and the control group, an analysis was conducted using the independent samples t-test. The results of the analysis are presented in Table 1 below.

Group	Mean	t-value	Sig. (p)
Experimental (AR)	85.6	3.45	0.001
Control	72.3	–	–

Based on Table 1, it can be seen that the average critical thinking score of students in the experimental group is 85.6, which is higher than that of the control group at 72.3. This difference in mean scores indicates an improvement in critical thinking skills among

students who used augmented reality-based diorama media. The statistical test results show a t-value of 3.45 with a significance value of $0.001 < 0.05$, indicating a significant difference between the two groups. This suggests that the use of AR-based diorama media has a significant effect on improving students' critical thinking skills compared to conventional learning.

Substantively, this improvement indicates that students in the experimental group are better able to perform higher-order thinking processes such as analyzing, evaluating, and drawing conclusions compared to students in the control group.

2. Learning Motivation

In addition to critical thinking skills, this study also examines students' learning motivation to determine the effect of AR-based diorama media on the affective domain. The results of the learning motivation analysis are presented in Table 2 below.

Group	Mean
Experimental (AR)	88.2
Control	74.5

Based on Table 2, the average learning motivation score of students in the experimental group is 88.2, while in the control group it is 74.5. This difference indicates that students who learned using AR-based diorama media have higher learning motivation compared to those who learned through conventional methods. Interpretatively, the higher learning motivation in the experimental group indicates that the use of AR-based media is able to increase students' interest, attention, and engagement in the learning process. Thus, AR-based diorama media not only affects the cognitive domain but also has a positive impact on the affective domain.

Discussion

The results of this study indicate that the use of augmented reality (AR)-based diorama media has a significant effect on improving students' critical thinking skills and learning motivation. These findings not only demonstrate statistical differences but also reflect substantial transformations in students' cognitive and affective learning processes.

From the perspective of critical thinking, the mean difference between the experimental group (85.6) and the control group (72.3) shows a gap of 13.3 points, indicating a practically significant effect. The significance value ($p = 0.001$) confirms that the treatment has a strong statistical impact. This finding supports the conceptual framework of critical thinking as a higher-order cognitive process involving interpretation, analysis, evaluation, and inference (Facione, 2015). In line with this, critical thinking is not limited to understanding information but extends to reflective and reasoned judgment (Ennis, 2018). The observed improvement suggests that AR-based learning environments effectively facilitate these higher-order thinking processes.

This enhancement can be analytically explained through active learning theory, where students are actively engaged in constructing knowledge through interaction and exploration (Bonwell, 2018). The AR-based diorama enables students to manipulate and observe learning objects directly, thereby fostering inquiry-based learning. This finding is consistent with previous studies showing that interactive digital media significantly improve students' critical thinking skills (Prasetyo, 2021). Moreover, experiential learning theory emphasizes that knowledge is constructed through concrete experiences, which are effectively supported by the integration of AR technology (Kolb, 2015).

From a constructivist perspective, learning occurs through active interaction with the environment (Piaget, 1972). The AR-based diorama functions as a form of scaffolding that bridges abstract scientific concepts with concrete representations. This aligns with Vygotsky's theory, which highlights the importance of mediated learning in cognitive development (Vygotsky, 1978). In the Indonesian context, technology-integrated learning media have been shown to enhance conceptual understanding and critical thinking abilities (Hidayat, 2022).

Furthermore, from the perspective of multimedia learning, the effectiveness of AR can be explained through dual-channel processing, where learners process information through visual and verbal channels simultaneously (Mayer, 2009). The three-dimensional visualization in AR reduces cognitive load and enhances information retention, allowing students to understand abstract concepts more efficiently. This is supported by research indicating that AR-based learning significantly improves conceptual understanding and engagement (Ibáñez et al., 2020; Radianti et al., 2020). Similarly, AR applications in education have been shown to provide meaningful and immersive learning experiences (Mustaqim, 2017).

In terms of learning motivation, the mean difference between the experimental group (88.2) and the control group (74.5) indicates a substantial increase of 13.7 points. This finding highlights the effectiveness of AR-based diorama media in enhancing students' motivation. Learning motivation plays a crucial role in determining students' engagement and academic achievement (Sardiman, 2018). Based on the ARCS model, motivation consists of attention, relevance, confidence, and satisfaction (Keller, 2010). The findings suggest that AR-based media successfully fulfills these four components.

Specifically, AR media captures students' attention through interactive visualization, enhances relevance by connecting abstract concepts with real-world contexts, builds confidence through independent exploration, and generates satisfaction through engaging learning experiences. These findings are consistent with previous studies demonstrating that AR significantly increases students' motivation and engagement (Chang et al., 2022). In the Indonesian context, interactive learning media have also been proven to improve students' motivation and participation (Lestari, 2022; Uno, 2019).

Moreover, the increase in motivation is not merely temporary but contributes to sustained engagement in learning. Students with higher motivation tend to demonstrate greater persistence, active participation, and deeper interest in the subject matter. Therefore, AR-based diorama media functions not only as an instructional tool but also as a psychological driver that enhances student engagement and learning sustainability.

Compared to previous studies, this research provides a more comprehensive contribution by integrating physical media (diorama) with digital technology (AR), resulting in a multimodal learning experience. Previous studies have predominantly focused on digital media alone, whereas this study combines tactile and visual elements simultaneously. This integration enables students not only to observe but also to experience learning concepts directly, which significantly enhances both cognitive and affective learning outcomes.

Overall, the findings indicate that the effectiveness of AR-based diorama media is not solely determined by technological innovation but also by its alignment with contemporary learning theories, including constructivism, multimedia learning, and active learning. The synergy between interactivity, concrete visualization, and student engagement emerges as the key factor in improving critical thinking skills and learning motivation simultaneously.

Conclusion

Overall, the results indicate that augmented reality-based diorama media is not only effective as a visualization tool but also plays a significant role in improving students' critical thinking skills and learning motivation. These findings confirm that the integration of interactive technology in science learning is a relevant approach to overcoming the limitations of abstract learning.

Recommendation

The results of this study indicate that augmented reality (AR)-based diorama media is effective in improving students' critical thinking skills and learning motivation. Practically, teachers are recommended to integrate this media into science learning, particularly in abstract topics such as the solar system, in order to create more concrete, interactive, and contextual learning experiences, as well as to encourage active student engagement through exploration. Theoretically, this study contributes to the development of technology-based learning by integrating physical and digital media, while also reinforcing constructivist and multimedia learning theories in enhancing conceptual understanding, critical thinking, and learning motivation simultaneously. In the context of educational policy, institutional support is needed in the form of technological infrastructure and teacher training to ensure the optimal implementation of AR-based media, as well as to serve as a reference for developing curricula that are adaptive to technological advancements. For future research, it is recommended to use larger and more diverse samples, test the effectiveness of the media across different educational levels and subject matters, explore additional variables such as higher-order thinking skills and collaborative skills, and apply longitudinal research designs to examine long-term impacts. The limitations of this study include the relatively small sample size, short research duration, and dependence on the availability of technological devices; therefore, further development is required to enhance the generalizability and practical implementation of the finding.

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