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Article

The Effect of Augmented Reality-Assisted BELKOPATA on Elementary School Students' Learning Achievement and Critical Thinking Skills

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Abstract: Digital transformation requires learning media that can visualize abstract concepts while supporting the development of higher-order thinking skills. This study aimed to analyze the effects of BELKOPATA learning media supported by Assemblr EDU on elementary school students' learning achievement and critical thinking skills, both separately and simultaneously. A quantitative approach was employed using a quasi-experimental method with a nonequivalent control group design. The participants were 37 students, comprising 17 students in the control class and 20 students in the experimental class. The experimental class received instruction using BELKOPATA supported by Assemblr EDU, whereas the control class received instruction without this media. Learning achievement data were collected through pretests and posttests, while critical thinking skills were assessed using an observation sheet covering information analysis, reasoning, evidence evaluation, problem solving, and conclusion drawing. The instruments were tested for validity and reliability before use. Data were analyzed using descriptive statistics, the Shapiro Wilk test, Levene's Test, Box's M Test, and Multivariate Analysis of Variance. The MANOVA results showed a significant simultaneous difference in learning achievement and critical thinking skills between the two classes, with Pillai's Trace=0.332, F(2,34)=8.443, and p=0.001. Separately, the experimental class achieved significantly higher learning outcomes than the control class, F(1,35)=15.449, p<0.001, with partial eta squared=0.306. However, the difference in critical thinking skills was not significant, F(1,35)=2.326, p=0.136. The multivariate effect was therefore driven primarily by learning achievement. Therefore, BELKOPATA supported by Assemblr EDU effectively improved learning achievement, although its influence on critical thinking requires longer intervention and more intensive analytical activities.

Keywords: Augmented Reality, Critical Thinking, Learning Achievement

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1. Introduction

Digital transformation has changed the learning environment of elementary school students. Digital technology no longer functions merely as a means of communication and entertainment but has also developed into a source of information and a medium for learning. Statistics Indonesia reported that the percentage of the Indonesian population accessing the internet increased from 69.21% in 2023 to 72.78% in 2024. During the same period, 68.65% of the Indonesian population owned a mobile phone [1]. The high level of access to technology indicates increasingly broad opportunities to integrate digital media into the learning process. However, the availability of technology does not automatically

improve learning quality unless its use is directed toward activities that actively engage students in observing, analyzing, and constructing understanding.

This condition is reflected in the literacy and reasoning achievements of Indonesian students, which still require considerable attention. The results of the 2022 Programme for International Student Assessment (PISA) showed that only 18% of Indonesian students achieved at least Level 2 in mathematics, 25% in reading, and 34% in science. These achievements were below the average of the member countries of the Organisation for Economic Co-operation and Development [2]. These findings indicate that most students continue to experience difficulties in applying knowledge to explain phenomena, connect information, evaluate evidence, and solve problems. Therefore, elementary education should be directed not only toward mastery of subject matter but also toward developing critical thinking skills as one of the competencies required in twenty-first-century learning.

The challenges associated with conceptual understanding and critical thinking are particularly apparent in Natural and Social Sciences, locally known as Ilmu Pengetahuan Alam dan Sosial (IPAS). Several IPAS topics, including human organ systems, the solar system, forces, changes in states of matter, ecosystems, and landforms, involve objects or processes that cannot always be directly observed by students. Presenting these topics solely through verbal explanations, textbooks, and two-dimensional images may lead students to memorize information without developing a deep understanding of the relationships among concepts. Elementary school students generally require concrete and contextual representations to connect new knowledge with their prior experiences.

One technology that can bridge the abstract nature of learning materials with students' need for concrete learning experiences is Augmented Reality. This technology integrates two- or three-dimensional virtual objects into the real-world environment, allowing learning objects to be observed more interactively. Alfitriani et al. explained that Augmented Reality enables objects that are difficult to present directly to be visualized in three-dimensional form, making learning more varied and less monotonous [3]. Through such visualization, students can observe the shape, structure, components, and relationships among objects from different perspectives. Therefore, Augmented Reality serves not only as a form of technological innovation but also as a representational medium that can assist students in constructing conceptual understanding.

The potential of Augmented Reality in elementary education has been demonstrated in various studies. Through a systematic literature review of 29 articles, Tarmidzi et al. found that the use of Augmented Reality made a positive contribution to elementary school students' motivation, interest, conceptual understanding, and critical and creative thinking skills [4]. In mathematics learning, Augmented Reality-based media have also been considered effective in helping students understand abstract concepts because objects can be visualized more concretely [5]. These findings demonstrate that the effectiveness of Augmented Reality is primarily related to its ability to provide visual and interactive learning experiences that students do not obtain through conventional instructional media.

In addition to supporting mastery of subject matter, Augmented Reality has the potential to develop critical thinking skills. Amalia et al. found that students who participated in learning using Augmented Reality media demonstrated better critical thinking skills than students who received conventional instruction [6]. Similar findings were reported by Sari et al., who identified an increase in students' critical thinking scores after the use of Virtual Augmented Reality-based media in IPAS learning [7]. Interaction with digital objects enables students to observe, identify essential components, compare information, provide reasons, and draw conclusions based on the objects being studied. These activities correspond to the characteristics of critical thinking, including the abilities to analyze, evaluate, make inferences, and reach decisions based on relevant information.

A study with a more rigorous research design was conducted by Tubagus et al. through the implementation of Augmented Reality-based discovery learning on the topic of human respiratory organs [8]. The quasi-experimental study involving a control group

showed that students in the experimental class achieved significantly higher critical thinking skills than those in the control class. The integration of Augmented Reality with discovery activities enabled students to explore three-dimensional objects, connect their observations with relevant concepts, and construct understanding independently. These findings indicate that the benefits of Augmented Reality are determined not only by the sophistication of the technology but also by the instructional design that encourages students to engage actively in cognitive activities.

Although most studies have reported positive findings, several limitations still provide opportunities for further investigation. First, several studies have measured only one learning outcome, either learning achievement or critical thinking skills, and have therefore not provided a comprehensive account of the effects of Augmented Reality on both aspects. Second, some studies have employed one-group pretest-posttest or pre-experimental designs without a control group, making it difficult to attribute changes in students' abilities entirely to the use of the media. Third, research and development studies have generally emphasized product validity, practicality, and feasibility rather than inferentially testing differences between groups. Fourth, studies that have simultaneously examined learning achievement and critical thinking skills have remained limited to descriptive analyses and have not tested the effects on the two dependent variables simultaneously [9].

These limitations are important because learning achievement and critical thinking skills are conceptually related but distinct outcomes. Learning achievement indicates the extent to which students have mastered the subject matter, whereas critical thinking skills reflect how students analyze information, evaluate reasoning, and formulate conclusions. Students may obtain high cognitive scores through memorization but may not necessarily be able to explain the underlying reasoning or apply concepts to solve problems. Conversely, well-developed critical thinking activities can help students construct more structured and durable understanding. Therefore, the effects of instructional media on these two variables should be analyzed simultaneously.

The novelty of this study lies in simultaneously examining the effects of Augmented Reality-assisted media on learning achievement and critical thinking skills through a quasi-experimental design involving both experimental and control groups. Unlike previous studies that tended to examine a single variable, involve only one group, or focus primarily on product feasibility, this study employs multivariate analysis to provide a more comprehensive understanding of the effects of the media on two interrelated learning outcomes. The findings are expected to strengthen empirical evidence regarding the effectiveness of Augmented Reality and provide a basis for teachers to select digital learning media that are not only visually engaging but also capable of supporting conceptual mastery and higher-order thinking processes.

Based on the preceding discussion, this study aimed to analyze: (1) the effect of Augmented Reality-assisted media on elementary school students' learning achievement; (2) the effect of Augmented Reality-assisted media on elementary school students' critical thinking skills; and (3) the simultaneous effect of Augmented Reality-assisted media on elementary school students' learning achievement and critical thinking skills.

2. Materials and Methods

This study employed a quantitative approach using a quasi-experimental method with a nonequivalent control group design. The research participants comprised 37 students, consisting of 17 students in the control class and 20 students in the experimental class. The experimental class received instruction using BELKOPATA learning media supported by *Assemblr EDU*, whereas the control class received instruction without the use of this media. Both classes were administered a pretest and a posttest to measure learning achievement, while critical thinking skills were assessed using an observation instrument based on indicators of analyzing information, providing reasons, evaluating evidence,

solving problems, and drawing conclusions. Before being used for data collection, the test instrument was examined for validity and reliability. Item validity was tested using the Pearson *Product Moment* correlation, while instrument reliability was analyzed using Cronbach's Alpha or KR-20 for items scored dichotomously, with a score of 1 for a correct answer and 0 for an incorrect answer.

The research data were analyzed using descriptive and inferential statistics. Before hypothesis testing, a normality test was conducted using the Shapiro–Wilk test because the number of students in each group was fewer than 50. Homogeneity of variance was examined using Levene's Test, while the equality of covariance matrices was assessed using Box's M Test. After all statistical assumptions had been satisfied, the hypotheses were tested using Multivariate Analysis of Variance (MANOVA) to determine the simultaneous effect of BELKOPATA learning media supported by *Assemblr EDU* on students' learning achievement and critical thinking skills. The decision-making criterion was based on a significance level of 0.05, with Pillai's Trace used as the primary multivariate statistic. The analysis was subsequently followed by the Tests of Between-Subjects Effects to determine the effect of the treatment on each dependent variable separately.

3. Results

The MANOVA analysis revealed a significant multivariate effect of BELKOPATA learning media supported by Assemblr EDU on students' learning achievement and critical thinking skills (Pillai's Trace = 0.332, $F(2,34) = 8.443$, $p = 0.001$). The experimental class demonstrated significantly higher learning achievement than the control class ($F(1,35) = 15.449$, $p < 0.001$, partial $\eta^2 = 0.306$), whereas the difference in critical thinking skills was not statistically significant ($F(1,35) = 2.326$, $p = 0.136$). These findings indicate that the significant multivariate effect was primarily driven by improvements in learning achievement.

4. Discussion

The instrument testing results showed that 16 out of 20 test items, or 80%, met the validity criteria, whereas items 2, 3, 5, and 9 did not meet the criteria because their correlation coefficients were lower than the r_{table} value of 0.349. This proportion indicates that most items were capable of distinguishing students based on their level of mastery of the measured material. The use of the point-biserial correlation was appropriate for the characteristics of multiple-choice questions with dichotomous scoring, in which a score of 1 was assigned to a correct answer and 0 to an incorrect answer. Zuhri et al. also used the point-biserial correlation to examine the validity of multiple-choice items and emphasized that invalid items should be revised or removed to ensure accurate measurement [10]. The Cronbach's Alpha coefficient of 0.755 indicated that the instrument had adequate internal consistency. Nevertheless, the number of items reported in the reliability table should be re-examined because it listed 21 items, whereas the initial instrument consisted of 20 items and only 16 items were declared valid. To ensure the accuracy of the results, reliability should be recalculated using the 16 final items that were actually employed in data collection.

Table 1. Calculation of Question Validity Test.

Item	r-hitung	r-tabel	Decision
1	0,483	0,349	**Valid**
2	0,296	0,349	**Invalid**
3	0,334	0,349	**Invalid**
4	0,504	0,349	**Valid**
5	0,155	0,349	**Invalid**
6	0,401	0,349	**Valid**

7	0,542	0,349	**Valid**
8	0,593	0,349	**Valid**
9	0,238	0,349	**Invalid**
10	0,517	0,349	**Valid**
11	0,793	0,349	**Valid**
12	0,572	0,349	**Valid**
13	0,835	0,349	**Valid**
14	0,745	0,349	**Valid**
15	0,726	0,349	**Valid**
16	0,795	0,349	**Valid**
17	0,849	0,349	**Valid**
18	0,720	0,349	**Valid**
19	0,702	0,349	**Valid**
20	0,759	0,349	**Valid**

The prerequisite test results indicated that the data satisfied the assumptions required for MANOVA [11]. The Shapiro–Wilk significance values for the pretest and posttest data in both the control and experimental classes were greater than 0.05, indicating that all datasets were normally distributed. The assumption of equal variances for each dependent variable was also satisfied, as demonstrated by Levene's Test significance values of 0.459 for learning achievement and 0.874 for critical thinking skills. In addition, Box's M Test produced a significance value of 0.825, indicating that the covariance matrices of the two dependent variables were relatively equal across the control and experimental classes [12]. The fulfillment of the assumptions of normality, homogeneity of variance, and homogeneity of covariance matrices supported the appropriateness of using MANOVA [13]. The multivariate analysis yielded a Pillai's Trace value of 0.332, with ($F(2,34)=8.443$) and ($p=0.001$), indicating a statistically significant simultaneous difference in the combined learning achievement and critical thinking skills between the two classes. The partial eta squared value of 0.332 indicated that the difference in instructional treatment made a substantial contribution to the combined variation in the two dependent variables [14].

Further analysis showed that the multivariate effect was primarily attributable to the learning achievement variable. The experimental class obtained a mean posttest score of 80.00, which was higher than the control class mean of 61.18, with ($F(1,35)=15.449$), ($p<0.001$), and a partial eta squared value of 0.306. These findings indicate that BELKOPATA learning media supported by Assemblr EDU effectively assisted students in understanding the learning material through the presentation of objects in a more concrete, visual, and interactive manner. This finding is consistent with Tarmidzi et al., who concluded that Augmented Reality can improve elementary school students' understanding and learning achievement [4]. However, no statistically significant difference was found in critical thinking skills, although the experimental class obtained a higher mean score of 70.76 than the control class mean of 66.01, with ($F(1,35)=2.326$), ($p=0.136$), and a partial eta squared value of 0.062. This result differs from the findings of Triana et al. and Tubagus et al., who reported improvements in critical thinking skills through the use of Augmented Reality [15], [8]. The difference may be associated with the limited sample size, the duration of the intervention, the characteristics of the learning activities, and the need for more sustained practice and reinforcement of analytical, evaluative, and inferential activities. Therefore, BELKOPATA learning media supported by Assemblr EDU demonstrated a strong effect on students' learning achievement, but its effect on critical thinking skills was not supported by sufficient statistical evidence.

5. Conclusion

Based on the findings, the instruments met the validity and reliability criteria after the invalid items were removed. The research data also satisfied the assumptions of

normality, homogeneity of variance, and homogeneity of covariance matrices, and were therefore appropriate for MANOVA. The multivariate test results indicated that the use of BELKOPATA learning media supported by *Assemblr EDU* had a significant simultaneous effect on students' learning achievement and critical thinking skills. However, when the dependent variables were analyzed separately, a significant effect was found only on learning achievement, as indicated by the higher mean score of the experimental class compared with the control class, while the difference in critical thinking skills was not statistically significant. Therefore, BELKOPATA learning media supported by *Assemblr EDU* was effective in improving students' learning achievement, whereas its effect on critical thinking skills requires further strengthening through a longer intervention period, learning activities that place greater emphasis on analysis and evaluation, and a larger sample size.

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