

# The Effectiveness of Augmented Reality (AR)-Based Learning Media on Elementary School Students' Interest and Science Learning Outcomes

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## Abstract

Augmented Reality (AR) offers opportunities to provide interactive and visually accessible learning experiences for elementary students, particularly for content that may be difficult to understand through conventional instruction alone. This study examined the effectiveness of AR-based learning media in supporting learning interest and learning outcomes in Grade III Science and Social Studies (IPAS) on the topic of Family and Community Traditions. A quantitative quasi-experimental approach with a nonequivalent control group design was employed. Participants were 40 Grade III students at SD Negeri Tambangan 01 Semarang, comprising 20 students in the experimental group and 20 in the control group. The experimental group received AR-supported instruction, whereas the control group received conventional instruction over two sessions. Data were collected using learning-outcome tests and a learning-interest questionnaire. The experimental group reported higher learning interest ( $M = 24.95$ ; 89.11%) than the control group ( $M = 19.45$ ; 69.46%). Learning-outcome means increased from 45.25 to 87.50 in the experimental group and from 42.50 to 72.25 in the control group. The experimental group achieved a mean N-Gain of .7619, while the reported independent-samples test indicated a significant between-group difference ( $t(38) = -2.929$ ,  $p = .006$ ). These findings provide evidence that AR-supported instruction has potential to enhance elementary IPAS learning, although further studies with larger samples and stronger baseline-adjusted analyses are needed.

**Keywords:** Augmented Reality, Elementary education, IPAS, Learning interest, Learning outcomes.

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## I. INTRODUCTION

Science and Social Studies (IPAS) is an important component of Indonesia's Merdeka Curriculum, integrating scientific and social perspectives to help students develop a comprehensive understanding of themselves, society, and their surrounding environment (Anita Cahyani, 2023). Beyond conceptual knowledge, IPAS learning is expected to support the development of thinking skills, social attitudes, and competencies relevant to students' everyday lives. Education more broadly also provides an important foundation for developing students' character and competencies (Kartika & Purwanda, 2024). However, achieving these objectives requires instructional practices capable of actively engaging students and making concepts accessible, particularly at the elementary school level.

In practice, IPAS instruction continues to encounter challenges related to student engagement and learning outcomes. Preliminary observations in Grade III at SD Negeri Tambangan 01 Semarang indicated that students tended to be passive during IPAS lessons. Classroom activities were predominantly characterized by listening to teacher explanations, while questioning, expressing opinions, and participating in discussions remained limited. Interviews with the classroom teacher further indicated that instruction relied largely on lectures and textbooks, with limited use of interactive learning media. Students were reported to lose attention easily and experience difficulty understanding abstract IPAS concepts. These conditions indicate a need for instructional media capable of representing learning content more concretely while encouraging active student participation.

Technology-supported learning provides one potential response to this instructional need. Digital technology can expand teachers' access to information and provide interactive resources that enrich classroom learning (Wal Ilham, 2022). As technological developments increasingly shape educational environments, instructional media are expected to move beyond their conventional function as information-delivery tools toward more interactive learning experiences (Miasari et al., 2022). Appropriate instructional media can facilitate the communication of learning content and help

students engage more effectively with information presented during instruction (Amri, 2025). Consequently, the pedagogical value of technology depends not simply on its availability but on how appropriately it is selected and integrated with learning objectives and students' characteristics.

One technology with particular potential for elementary education is Augmented Reality (AR). AR integrates digitally generated objects or information with representations of the physical environment, allowing learners to interact with content that might otherwise be difficult to visualize. Such characteristics are particularly relevant to learning materials involving abstract or context-dependent concepts. Previous literature suggests that technology-enhanced and AR-supported environments can provide engaging learning experiences and facilitate students' conceptual understanding (Socrates Putra & Mufit, 2022; Ghanbaripour Naser et al., 2024). The use of appropriate instructional media may also contribute to the quality and efficiency of learning processes (Shabrina, 2025). For elementary school students, therefore, AR may offer a means of transforming abstract or text-dominated content into more concrete and visually accessible learning experiences.

The potential contribution of AR is relevant not only to cognitive learning outcomes but also to learning interest. Interest can influence students' willingness to direct attention, participate in classroom activities, and persist in learning tasks. This dimension is particularly important when students encounter content that they perceive as abstract or difficult. Interactive visualization through AR may provide novelty and opportunities for exploration that encourage students to engage more actively with learning materials. At the same time, enhanced visualization may facilitate conceptual processing and thereby support cognitive learning outcomes. Examining these two outcomes simultaneously is important because increased interest does not necessarily imply improved academic achievement, and improved achievement cannot automatically be interpreted as evidence of stronger learning interest.

Previous empirical studies provide preliminary support for the educational potential of AR. Zendarto Nirmala Ikhsanat et al. (2025), in a study involving 32 students, reported a 21.27% increase in learning interest following the use of AR-based media. This finding suggests that AR-supported learning may contribute to a more engaging classroom experience. Meanwhile, Ginting et al. (2025) reported improvement in students' learning outcomes following AR-supported instruction, including an increase from a pretest mean of 64.48 to a posttest mean of 85.20. Together, these studies indicate potential benefits of AR for both affective and cognitive dimensions of learning.

Nevertheless, important gaps remain in the existing evidence. Previous studies have generally examined learning interest and learning outcomes separately, making it difficult to determine whether AR-supported instruction is associated with improvements in both dimensions within the same learning context. Furthermore, differences in subject matter, educational level, and student characteristics limit the direct applicability of previous findings to Grade III IPAS instruction. Evidence remains particularly limited regarding the use of AR for the IPAS topic Family and Community Traditions (*Tradisi Keluarga dan Masyarakat Sekitar*), which requires students to understand social and cultural phenomena that may benefit from contextual and visual representation.

Accordingly, this study aimed to examine the effectiveness of Augmented Reality-based learning media in supporting Grade III students' learning interest and learning outcomes in IPAS, specifically on the topic of Family and Community Traditions at SD Negeri Tambangan 01 Semarang. By examining both learning interest and cognitive learning outcomes within the same study, this research seeks to provide a more comprehensive account of AR-supported IPAS learning than studies focusing on either outcome independently. The findings are expected to contribute empirical evidence regarding the pedagogical use of AR in elementary IPAS instruction and inform the development of interactive learning environments that are responsive to the learning characteristics of young students.

## II. METHOD

This study employed a quantitative quasi-experimental design with a nonequivalent control group design to examine the effectiveness of Augmented Reality (AR)-based learning media in supporting students' learning interest and learning outcomes in IPAS. The study was conducted with

Grade III students at SD Negeri Tambangan 01 Semarang, Mijen District. The population comprised all 40 Grade III students distributed across two intact classes. Because of the relatively small population, total sampling was applied, with all students included in the study. Class IIIA, consisting of 20 students, served as the control group, while Class IIIB, also consisting of 20 students, served as the experimental group. Because students remained in their existing classes and were not individually randomized to conditions, the study was classified as quasi-experimental rather than a true randomized experiment.

Both groups received instruction on the same IPAS topic, Family and Community Traditions (Tradisi Keluarga dan Masyarakat Sekitar), over two instructional sessions. Before instruction, students in both groups completed a pretest to establish their initial learning-outcome scores. The control group subsequently received conventional instruction, whereas the experimental group received instruction supported by Augmented Reality-based learning media. Following the instructional period, both groups completed the same posttest and a learning-interest questionnaire. Thus, learning outcomes were measured before and after instruction, whereas learning interest was assessed after the intervention.

Data were collected using both test and non-test techniques. The pretest and posttest were administered to measure students' cognitive learning outcomes and to examine changes occurring during the instructional period. Non-test data were obtained through a learning-interest questionnaire, classroom observations, interviews, and documentation. The questionnaire was used to assess students' learning interest following instruction, while observations and interviews were employed primarily during the preliminary stage to identify existing IPAS learning conditions and classroom-related problems. Documentation provided supporting information, including instructional materials, student records, and records of research activities.

The learning-interest questionnaire was developed based on the indicators proposed by Rozikin et al. (2018, as cited in Hidayah, Cahyadi et al., 2023), encompassing enjoyment, interest, attention, involvement, and feelings of pride and satisfaction in learning. Prior to data collection, the learning-outcome test and learning-interest questionnaire were evaluated for validity and reliability to ensure their appropriateness for the study.

Data analysis consisted of descriptive and inferential statistical procedures. Descriptive statistics were used to summarize students' learning outcomes and learning-interest scores. Before hypothesis testing, normality and homogeneity tests were conducted to examine the relevant statistical assumptions. An independent-samples t-test was then used to compare the experimental and control groups in terms of post-intervention learning outcomes and learning interest. In addition, N-Gain analysis was employed to describe the magnitude of improvement in learning outcomes from pretest to posttest.

### III. RESULTS AND DISCUSSION

#### A. Results

##### 1. Instrument Validity and Reliability

Before data collection, the learning-outcome test and learning-interest questionnaire were evaluated for validity and reliability. The initial learning-outcome instrument consisted of 50 items. Validity testing identified 26 valid items, from which 20 items were selected based on their alignment with the intended learning indicators. The resulting instrument demonstrated high internal consistency, with a Cronbach's alpha of .935. The learning-interest questionnaire initially consisted of 20 items, of which 7 items met the validity criteria and were retained for the study. The questionnaire obtained a Cronbach's alpha of .674, indicating acceptable internal consistency based on the criterion adopted in this study.

**Table 1.** Validity and Reliability of the Research Instruments

| Instrument                      | Initial Items | Valid Items Used | Cronbach's $\alpha$ |
|---------------------------------|---------------|------------------|---------------------|
| Learning-Outcome Test           | 50            | 20*              | .935                |
| Learning-Interest Questionnaire | 20            | 7                | .674                |

## 2. Learning Interest

Students' learning interest was assessed after the instructional intervention in both groups. The results are presented in Table 2.

**Table 2.** Descriptive Results for Learning Interest

| Group        | N  | Total Score | Mean  | Percentage | Category  |
|--------------|----|-------------|-------|------------|-----------|
| Control      | 20 | 389         | 19.45 | 69.46%     | Moderate  |
| Experimental | 20 | 499         | 24.95 | 89.11%     | Very High |

The experimental group obtained a mean learning-interest score of 24.95 (89.11%), categorized as very high, whereas the control group obtained a mean of 19.45 (69.46%), categorized as moderate. Descriptively, therefore, students who received AR-supported instruction reported higher learning interest than those who received conventional instruction.

## 3. Assumption Testing for Learning Outcomes

Normality was examined using the Shapiro–Wilk test for the pretest and posttest scores of both groups.

**Table 3.** Shapiro–Wilk Normality Test

| Measurement           | Statistic | df | <i>p</i> |
|-----------------------|-----------|----|----------|
| Control Pretest       | .933      | 20 | .178     |
| Control Posttest      | .959      | 20 | .528     |
| Experimental Pretest  | .963      | 20 | .609     |
| Experimental Posttest | .928      | 20 | .144     |

All Shapiro–Wilk tests were nonsignificant ( $p > .05$ ), providing no evidence of substantial departures from normality in any of the four distributions. Homogeneity of variance was subsequently examined using Levene's test.

**Table 4.** Levene's Test for Homogeneity of Variance

| Test                             | Levene Statistic | df2    | <i>p</i> |
|----------------------------------|------------------|--------|----------|
| Based on Mean                    | 2.036            | 38     | .162     |
| Based on Median                  | 2.100            | 38     | .156     |
| Based on Median with Adjusted df | 2.100            | 35.557 | .156     |
| Based on Trimmed Mean            | 2.035            | 38     | .162     |

The conventional Levene test based on the mean was nonsignificant ( $p = .162$ ), indicating no evidence of unequal variances between the groups. The reported assumption checks therefore supported the use of parametric between-group analysis.

## 4. Descriptive Analysis of Learning Outcomes

Table 5 summarizes students' pretest and posttest learning-outcome scores.

**Table 5.** Descriptive Statistics for Learning Outcomes

| Group        | N  | Pretest Mean | Posttest Mean | Mean Increase |
|--------------|----|--------------|---------------|---------------|
| Experimental | 20 | 45.25        | 87.50         | 42.25         |
| Control      | 20 | 42.50        | 72.25         | 29.75         |

The two groups showed relatively similar descriptive pretest means, with 45.25 in the experimental group and 42.50 in the control group. Following instruction, the experimental group achieved a posttest mean of 87.50, representing an increase of 42.25 points, whereas the control group increased from 42.50 to 72.25, corresponding to an increase of 29.75 points. Thus, both groups improved descriptively, but the experimental group demonstrated a larger increase.

## 5. Between-Group Comparison of Learning Outcomes

An independent-samples t-test was conducted to compare learning outcomes between the experimental and control groups.

**Table 6.** Independent-Samples t-Test for Learning Outcomes

| Comparison               | Mean Difference | <i>t</i> | df | <i>p</i> |
|--------------------------|-----------------|----------|----|----------|
| Experimental vs. Control | -9.250          | -2.929   | 38 | .006     |

The analysis indicated a statistically significant difference between the groups,  $t(38) = -2.929$ ,  $p = .006$ . This finding indicates that the scores compared in the independent-samples analysis differed significantly between the experimental and control groups. Together with the descriptive results, the findings provide evidence of different learning outcomes between the two instructional conditions.

## 6. N-Gain Analysis

N-Gain analysis was additionally conducted for the 20 students in the experimental group to describe the magnitude of improvement from pretest to posttest.

**Table 7.** N-Gain for the Experimental Group

| Group        | N  | Mean N-Gain | Category |
|--------------|----|-------------|----------|
| Experimental | 20 | .7619       | High     |

The experimental group obtained a mean N-Gain of .7619, indicating a high normalized improvement in learning outcomes following AR-supported instruction. This result is consistent with the substantial descriptive increase from the experimental group's pretest mean (45.25) to its posttest mean (87.50).

## B. Discussion

The findings indicate that students who participated in Augmented Reality (AR)-supported IPAS instruction demonstrated greater classroom engagement and higher post-intervention learning interest than those who received conventional instruction. During classroom implementation, students in the experimental group were observed to participate actively in operating the AR media, exploring the visual representations, and attending to the accompanying audio explanations. These features provided opportunities for students to engage with the topic of Family and Community Traditions through representations that were more interactive and concrete than textbook-based materials alone. Such engagement is consistent with the conceptualization of learning interest through enjoyment, attraction, attention, and active involvement in learning activities (Furqon, Muhammad, S.E., 2024).

The descriptive learning-interest findings support these classroom observations. Students in the experimental group obtained a mean score of 24.95 (89.11%), categorized as very high, compared with 19.45 (69.46%) in the control group. This pattern suggests that AR-supported instruction was associated with greater student interest during IPAS learning. AR may be particularly relevant in this context because it combines digital information with representations of the physical environment, enabling students to explore instructional content in ways that are visually engaging and contextually meaningful (Samala et al., 2023). Interactive features may stimulate curiosity and sustain attention, both of which are closely related to students' willingness to participate in learning activities (Mohzan, 2023; Mesra et al., 2021). Similarly, Rasyida and Rasim (2025) emphasize the potential of attractive AR features to create engaging learning environments.

Nevertheless, the difference in learning interest should be interpreted primarily as a descriptive finding because the reported analysis provides group means and percentages but does not yet present an inferential between-group test for the learning-interest scores. Consequently, the present evidence supports the observation that the experimental group reported higher learning interest, but statistical evidence is still required to establish whether the difference is unlikely to have occurred by sampling variation. This distinction is important because the study

seeks to examine both learning interest and learning outcomes rather than cognitive outcomes alone.

A clearer pattern emerged for students' learning outcomes. The experimental group increased from a pretest mean of 45.25 to a posttest mean of 87.50, representing a descriptive increase of 42.25 points. The control group also improved, from 42.50 to 72.25, corresponding to an increase of 29.75 points. Thus, improvement occurred under both instructional conditions, although the increase was descriptively larger among students who received AR-supported instruction. The experimental group also obtained a mean N-Gain of .7619, indicating a high normalized improvement over the instructional period.

The reported independent-samples analysis further indicated a statistically significant between-group difference,  $t(38) = -2.929$ ,  $p = .006$ . Taken together, the descriptive improvement and between-group analysis suggest that the instructional conditions were associated with different learning outcomes. However, because this study employed a nonequivalent control group design using intact classes, the findings should not be interpreted as definitive evidence that AR alone caused the observed difference. Student characteristics, classroom dynamics, teacher-student interaction, and other contextual factors may also have contributed to learning outcomes. The findings therefore provide evidence supporting the educational potential of AR within the context investigated rather than establishing an isolated causal effect of the technology.

One plausible pedagogical explanation concerns AR's capacity to provide concrete and visually accessible representations. Grade III students may benefit from instructional experiences that connect concepts to observable objects, situations, and familiar contexts rather than relying predominantly on verbal explanations. This characteristic is particularly relevant to the IPAS topic of Family and Community Traditions, for which students need to connect social and cultural concepts with practices encountered in everyday life. By integrating virtual objects with representations of real-world contexts, AR can potentially reduce the abstraction of learning materials and provide richer opportunities for students to construct meaning. Samala et al. (2023) similarly describe AR as an integration of virtual and physical environments capable of creating novel and engaging learning experiences.

The findings are also consistent with previous empirical studies. Erlina et al. (2025) reported an increase in students' learning interest following AR-supported instruction, with the reported proportion increasing from 40% to 60%. Regarding cognitive outcomes, Atfaliyah et al. (2025) reported an increase in the experimental group's mean learning score from 53.57 to 85.18 after AR-supported learning. These findings collectively suggest that AR has potential to support both students' engagement with learning activities and their cognitive outcomes. The present study extends this evidence to Grade III IPAS instruction on Family and Community Traditions, a context in which evidence on AR implementation remains comparatively limited.

An important contribution of the present study is its simultaneous consideration of learning interest and learning outcomes. These constructs represent related but distinct dimensions of the learning process. Greater interest may encourage students to direct attention toward instructional activities, explore learning resources, ask questions, and remain involved in learning tasks, whereas learning outcomes represent students' demonstrated cognitive achievement following instruction. The classroom observations suggest that AR created more opportunities for active engagement, while the learning-outcome data indicate substantial improvement during the intervention period. However, the present design does not establish whether increased learning interest mediated the improvement in learning outcomes; such a mechanism would require direct statistical testing in future research.

The implementation also revealed practical challenges. Differences in mobile-device specifications and unstable internet connectivity occasionally affected access to the AR media. These constraints are important because the instructional benefits of AR depend partly on adequate technological infrastructure and reliable access to compatible devices. Future implementation should therefore consider technical readiness, offline or low-bandwidth alternatives, device compatibility, and teacher preparation before AR is incorporated into routine classroom instruction.

Overall, the findings provide encouraging evidence for the use of AR as an interactive instructional medium in elementary IPAS learning. The combination of higher descriptive learning-interest scores, substantial pretest–posttest improvement in the experimental group, and the reported significant between-group difference suggests that AR-supported instruction has potential to enrich students’ learning experiences. Nevertheless, these findings should be interpreted within the study’s limitations, including the small sample of 40 students from a single school, the use of intact classes without individual randomization, the short two-session intervention, and the absence of a reported inferential comparison for learning interest. Future studies should involve larger and more diverse samples, longer intervention periods, and stronger baseline-adjusted analyses to determine whether the observed benefits can be replicated and sustained across different elementary school contexts.

#### IV. CONCLUSION

This study examined the use of Augmented Reality (AR)-based learning media in Grade III IPAS instruction on the topic of Family and Community Traditions. Students in the experimental group demonstrated higher descriptive learning interest ( $M = 24.95$ ; 89.11%) than those in the control group ( $M = 19.45$ ; 69.46%). Learning outcomes also improved in both groups, with the experimental group increasing from 45.25 to 87.50 and the control group from 42.50 to 72.25. The experimental group achieved a mean N-Gain of .7619, indicating high normalized improvement, while the reported independent-samples analysis showed a significant between-group difference ( $t(38) = -2.929$ ,  $p = .006$ ). These findings suggest that AR-supported instruction has potential to promote engaging and visually accessible IPAS learning while supporting students’ cognitive outcomes. Nevertheless, the findings should be interpreted cautiously because the study involved only 40 students from one school, used intact classes without individual randomization, and implemented the intervention over only two sessions. In addition, the difference in learning interest was established descriptively rather than inferentially. Future studies should employ larger samples, longer interventions, and baseline-adjusted analyses to provide stronger evidence regarding the effectiveness and sustainability of AR-supported elementary learning.

#### CONFLICT OF INTEREST

*The authors declare that they have no financial, professional, institutional, or personal conflicts of interest that could have influenced the design, implementation, analysis, interpretation, or reporting of this study.*

#### AUTHOR CONTRIBUTIONS

**Tutik Ratna Ningtyas:** conceptualization, research design, data collection, data analysis, interpretation of findings, and preparation of the original manuscript. **Amirudin:** methodology, research supervision, interpretation of findings, and manuscript review and editing. **Prihatin Puji Astuti:** theoretical framework development, methodological guidance, interpretation of findings, and critical revision of the manuscript. All authors reviewed and approved the final version of the manuscript.

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#### DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES

*Generative artificial intelligence tools were used solely to support language editing, proofreading, translation, and improvement of the manuscript’s clarity and readability. AI tools were not used to generate or modify research data, perform statistical analyses, or determine the study findings and*

conclusions. All AI-assisted revisions were carefully reviewed and verified by the authors, who retain full responsibility for the accuracy, originality, and integrity of the final manuscript.

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