

DEVELOPMENT OF AUGMENTED REALITY LEARNING MEDIA FOR INTEGRATED SCIENCE AND SOCIAL STUDIES (IPAS) INSTRUCTION TO IMPROVE ELEMENTARY SCHOOL STUDENTS' CONCEPTUAL UNDERSTANDING

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ARTICLE INFO

Article history:

Received : June 10, 2026

Revised : June 15, 2026

Accepted : June 22, 2026

Available online : June 25, 2026

Kata Kunci:

Augmented Reality,
Pembelajaran IPAS,
Pemahaman Konsep, Sekolah
Dasar, Media Pembelajaran

Keywords:

Augmented Reality, IPAS
Learning, Conceptual
Understanding, Elementary
School, Learning Media

ABSTRAK

Penelitian ini bertujuan untuk mengembangkan media pembelajaran berbasis Augmented Reality (AR) pada mata pelajaran Ilmu Pengetahuan Alam dan Sosial (IPAS) di sekolah dasar guna meningkatkan pemahaman konsep siswa. Penelitian menggunakan metode Research and Development (R&D) dengan model pengembangan ADDIE (Analysis, Design, Development, Implementation, Evaluation). Subjek penelitian adalah siswa kelas V SDN Gunong Kleng yang berjumlah 32 orang. Instrumen yang digunakan meliputi lembar validasi ahli media, ahli materi, angket respons siswa, dan soal tes pemahaman konsep. Hasil validasi ahli media memperoleh rata-rata skor 88,5% (sangat layak) dan validasi ahli materi 85,2% (sangat layak). Uji coba lapangan menunjukkan peningkatan pemahaman konsep siswa dengan nilai rata-rata pretest 61,3 meningkat menjadi 82,7 pada posttest, dengan N-Gain sebesar 0,55 (kategori sedang). Respons siswa terhadap media AR menunjukkan kategori sangat positif dengan skor 91,4%. Dengan

demikian, media pembelajaran berbasis Augmented Reality layak dan efektif digunakan dalam pembelajaran IPAS di sekolah dasar.

ABSTRACT

This study aims to develop Augmented Reality (AR)-based learning media for Natural and Social Science (IPAS) subject in elementary schools to improve students' conceptual understanding. The research employed the Research and Development (R&D) method with the ADDIE development model (Analysis, Design, Development, Implementation, Evaluation). The research subjects were 32 fifth-grade students of SDN Gunong kleng. The instruments used included media expert validation sheets, content expert validation sheets, student response questionnaires, and concept understanding tests. Media expert validation obtained an average score of 88.5% (very feasible) and content expert validation 85.2% (very feasible). Field trials showed an improvement in students' conceptual understanding with an average pretest score of 61.3 increasing to 82.7 on the posttest, with an N-Gain of 0.55 (moderate category). Student responses to the AR media showed a very positive category with a score of 91.4%. Thus, Augmented Reality-based learning media is feasible and effective to use in IPAS learning in elementary schools.

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INTRODUCTION

The rapid advancement of information and communication technology has significantly transformed various sectors of human life, including education. In the twenty-first century, educational institutions are expected to integrate digital technologies into teaching and learning processes to create meaningful, engaging, and student-centered learning experiences. Technology-based learning media have become essential tools for supporting the achievement of learning objectives, fostering students' active participation, and improving learning outcomes. The integration of digital technology in education is also aligned with the demands of Industry 4.0 and Society 5.0, which require students to possess critical thinking, problem-solving, creativity, communication, and digital literacy skills. Recent studies have shown that the successful adoption of digital learning technologies depends not only on infrastructure, but also on teachers' pedagogical readiness and institutional digital leadership (Graser & Böhm, 2024; Nelson & Gabbard, 2024). Therefore, schools need to adopt innovative learning media that can facilitate students' understanding of complex concepts while increasing their motivation and engagement in learning activities (Tansha & Siregar, 2026).

In Indonesia, the implementation of the Merdeka Curriculum has encouraged educators to design learning experiences that are more contextual, interactive, and meaningful. One of the distinctive features of this curriculum is the introduction of *Ilmu Pengetahuan Alam dan Sosial* (IPAS), an integrated subject that combines concepts from natural sciences and social sciences at the elementary school level. The integration of these disciplines aims to help students understand natural and social phenomena holistically, enabling them to relate scientific concepts to real-life situations. Through IPAS, students are expected to develop scientific literacy, social awareness, critical thinking skills, and environmental responsibility. However, achieving these objectives requires learning approaches and media that can effectively support students in understanding abstract and interconnected concepts. Recent reviews on augmented reality in primary and science education also indicate that technology-enhanced instruction is particularly effective when it is aligned with curriculum goals and contextual learning demands (Cabero-Almenara et al., 2023; Alzahrani et al., 2023).

Despite its importance, IPAS learning presents several challenges, particularly for elementary school students. Many topics in IPAS involve abstract concepts that are difficult to visualize through conventional teaching methods. Topics such as the solar system, water

cycles, ecosystems, planetary motion, environmental interactions, and the relationship between humans and their surroundings require students to construct mental representations of objects and processes that cannot be directly observed. Elementary school students are generally in the concrete operational stage of cognitive development, meaning that they learn more effectively when concepts are presented through concrete experiences and visual representations. Consequently, relying solely on textbooks, verbal explanations, and static images often limits students' ability to develop a deep understanding of these concepts. Systematic reviews have consistently shown that augmented reality (AR) is effective in helping learners visualize abstract phenomena and bridge the gap between concrete and symbolic representations (Garzón et al., 2021; Chen et al., 2022).

Conceptual understanding is a crucial aspect of learning because it reflects students' ability to comprehend, interpret, and apply knowledge rather than merely memorizing facts. Students with strong conceptual understanding can explain relationships among concepts, solve problems in different contexts, and transfer their knowledge to new situations. In contrast, students who learn through rote memorization tend to experience difficulties when confronted with unfamiliar problems or real-world applications. Therefore, improving conceptual understanding has become one of the primary goals of contemporary education (Fistiana, 2026). Effective learning media play a significant role in achieving this objective by helping students visualize abstract concepts and engage in meaningful learning experiences. Recent empirical studies have confirmed that AR-based instruction can improve conceptual understanding, achievement, and retention in science learning because it supports spatial reasoning and deeper cognitive processing (Hwang et al., 2022; Yilmaz et al., 2024).

Recent studies have highlighted the importance of digital learning innovations in enhancing students' learning outcomes. Erlita (2025) emphasized that digital leadership demonstrated by school principals and teachers plays a critical role in addressing students' digital readiness gaps. Educational institutions that effectively integrate digital technologies into classroom practices are more likely to foster active learning environments and improve students' learning experiences. This finding indicates that the successful implementation of innovative learning technologies requires not only technological infrastructure but also a commitment from educational stakeholders to support digital transformation in schools. Similarly, Herawati (2025) reported that the development of

STEM-based interactive e-modules significantly improved elementary school students' critical thinking skills. The study demonstrated that interactive digital learning resources can facilitate students' active engagement and promote deeper understanding of learning materials. These findings suggest that technology-enhanced learning media have considerable potential to support cognitive development and improve learning quality in elementary education. Furthermore, Iswadi (2025) found that project-based publicity strategies contributed positively to students' creativity and digital literacy development. The integration of technology and innovative pedagogical approaches was shown to encourage students to become active participants in the learning process rather than passive recipients of information. In line with these findings, recent reviews also emphasize that the pedagogical design of digital media is a decisive factor in determining learning effectiveness (Manisha & Gargrish, 2023).

Among various educational technologies, Augmented Reality (AR) has emerged as one of the most promising innovations for enhancing learning experiences. Augmented Reality is a technology that overlays virtual objects onto the real-world environment in real time, creating an interactive and immersive learning experience. Unlike traditional multimedia resources, AR enables learners to interact with three-dimensional virtual objects as if they were part of the physical environment. This capability allows students to observe, manipulate, and explore learning materials in ways that are difficult or impossible to achieve through conventional methods. As a result, AR has attracted considerable attention from researchers and educators seeking to improve learning effectiveness and student engagement. Recent systematic reviews have confirmed that AR is particularly valuable in educational contexts that require spatial visualization, experiential learning, and active exploration (Garzón et al., 2021; Cabero-Almenara et al., 2023).

The educational benefits of AR have been documented in numerous studies. Research indicates that AR can enhance students' motivation, engagement, spatial understanding, and conceptual comprehension by providing realistic visualizations of abstract phenomena. Through interactive three-dimensional representations, students can better understand relationships among concepts and develop stronger cognitive connections. In science education, for example, AR enables students to visualize microscopic structures, astronomical objects, and scientific processes that are otherwise inaccessible. Similarly, in social studies education, AR can facilitate exploration of historical events, geographical features, and cultural artifacts in more meaningful and engaging

ways. Meta-analytic and review studies have shown that AR consistently produces positive effects on learning achievement, interest, and conceptual learning, especially when it is integrated with inquiry-based or student-centered instruction (Chen et al., 2022; Alzahrani et al., 2023).

Previous studies have demonstrated positive effects of AR on students' learning outcomes. Syam et al. (2026) found that AR-based learning significantly improved students' motivation and understanding of scientific concepts. The immersive nature of AR was shown to increase students' curiosity and participation during classroom activities. Likewise, Salsabila (2026) reported that AR provided substantial advantages in terms of visualization, interaction, and student engagement. Students who learned using AR-based media exhibited higher levels of interest and achieved better learning outcomes compared to those who learned through conventional instructional approaches. These findings indicate that AR has strong potential to address learning challenges associated with abstract concepts. Similar conclusions were also reported in recent empirical studies showing that AR can improve elementary students' science achievement and conceptual understanding when the media are designed to support active exploration and guided discovery (Hwang et al., 2022; Yilmaz et al., 2024).

Although the effectiveness of AR has been widely acknowledged, several gaps remain in the existing literature. First, many previous studies have focused primarily on science subjects or specific disciplinary content rather than integrated learning contexts such as IPAS. Given that IPAS combines concepts from natural and social sciences, the design and implementation of AR-based learning media require different considerations compared to single-subject applications. Second, most existing studies have emphasized learning motivation, satisfaction, or general academic achievement, while relatively few have specifically examined conceptual understanding as the primary learning outcome. Considering that conceptual understanding is a key objective of IPAS learning, this gap warrants further investigation. Third, research on AR implementation within the framework of the Merdeka Curriculum remains limited. Since the curriculum emphasizes student-centered learning, inquiry, and contextual understanding, there is a need to develop learning media that align with these principles. AR offers opportunities to support experiential and exploratory learning; however, empirical evidence regarding its effectiveness in Merdeka Curriculum contexts is still insufficient. Fourth, many previous studies have been conducted in urban schools with relatively advanced technological

facilities, whereas evidence from schools with limited learning resources remains scarce. This limitation raises questions regarding the applicability and effectiveness of AR-based learning media in diverse educational settings. Recent reviews also note that future AR research should move beyond general effectiveness claims and examine context-specific implementation, pedagogical design, and learning outcomes such as conceptual understanding in elementary education (Alzahrani et al., 2023; Hidajat, 2024; Nelson & Gabbard, 2024).

Preliminary observations conducted at SDN Gunong Kleng revealed several challenges in IPAS learning. Most fifth-grade students experienced difficulties in understanding abstract concepts, particularly in the topic of the solar system. Students often struggled to visualize planetary structures, orbital movements, and spatial relationships among celestial bodies when learning through textbooks and teacher explanations alone. The average score of students' daily assessments on the solar system topic was 62.5, which was below the Minimum Learning Achievement Criteria (*Kriteria Ketercapaian Tujuan Pembelajaran*—KKTP) of 70. Interviews with teachers also indicated that existing learning media were limited and lacked the ability to present concepts in concrete, interactive, and engaging forms. Consequently, students' participation and conceptual understanding remained relatively low.

Considering these challenges, the development of AR-based learning media represents a promising solution. By enabling students to interact with three-dimensional models of planets and other astronomical objects, AR can transform abstract concepts into tangible learning experiences. Such experiences are expected to facilitate knowledge construction, strengthen conceptual understanding, and improve learning outcomes (Salsabila, 2026). Furthermore, AR-based learning media are consistent with the principles of the Merdeka Curriculum, which encourage active learning, exploration, and the integration of technology into classroom instruction. Recent studies have also shown that AR is most effective when it is designed as a pedagogically structured medium rather than as a mere technological novelty (Garzón et al., 2021; Cabero-Almenara et al., 2023).

Based on the theoretical considerations, empirical evidence, and identified research gaps, this study aims to develop Augmented Reality learning media for IPAS instruction, particularly on the solar system topic for fifth-grade elementary school students. Specifically, the study seeks to: (1) develop AR-based learning media for IPAS instruction; (2) evaluate the feasibility of the developed media through expert validation; (3) analyze

the effectiveness of AR-based learning media in improving students' conceptual understanding; and (4) examine students' responses to the implementation of AR in learning activities. The findings of this study are expected to contribute to the advancement of technology-enhanced learning in elementary education, provide empirical evidence regarding the role of AR in improving conceptual understanding, and offer practical recommendations for implementing innovative learning media within the Merdeka Curriculum framework (Syam et al., 2026).

RESEARCH METHOD

This study used a Research and Development (R&D) approach to develop and test an Augmented Reality (AR)-based learning medium for Integrated Science and Social Studies (*Ilmu Pengetahuan Alam dan Sosial*—IPAS). The development process followed the ADDIE model, which includes Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009).

Research Design

The study began with an Analysis stage to identify learning problems, student characteristics, curriculum needs, and the difficulties students faced in understanding the solar system topic. In the Design stage, the learning media blueprint was prepared, including the storyboard, interface, learning flow, marker design, and assessment instruments based on the Merdeka Curriculum.

The Development stage involved creating 3D objects, integrating them into an AR application using Unity and Vuforia, and revising the prototype based on expert feedback. During Implementation, the product was tested through a limited trial and a field trial with fifth-grade students. The Evaluation stage was carried out throughout the process to improve the product and determine its feasibility and effectiveness.

Participants

The participants were 32 fifth-grade students at SDN Gunong Kleng in the 2025/2026 academic year. They were selected because they had studied the solar system topic and were the target users of the developed media.

Product validation involved four experts: two media experts and two IPAS material experts.

Instruments

Data were collected using three instruments:

1. **Expert Validation Questionnaires**

Used to assess media feasibility in terms of design, usability, content accuracy, and curriculum alignment.

2. **Student Response Questionnaire**

Used to measure students' perceptions of attractiveness, ease of use, engagement, and learning experience.

3. **Conceptual Understanding Test**

Administered as pre-test and post-test to measure students' understanding of solar system concepts before and after using the AR media.

Data Analysis

Validation and questionnaire data were analyzed descriptively and converted into percentage scores. Media feasibility was interpreted using standard percentage criteria.

To measure learning effectiveness, N-Gain scores were calculated using the formula:

$$\text{N-Gain} = (\text{Post-test Score} - \text{Pre-test Score}) / (\text{Maximum Score} - \text{Pre-test Score})$$

The N-Gain results were interpreted as high, moderate, or low based on Hake's criteria. In addition, a paired-samples t-test was used to determine whether the difference between pre-test and post-test scores was statistically significant at the 0.05 level.

Validity and Reliability

All instruments were validated by experts before use. Reliability testing was conducted using Cronbach's Alpha, and instruments with coefficients above 0.70 were considered reliable.

Through these procedures, the study aimed to produce a valid, practical, and effective AR learning medium for improving elementary students' conceptual understanding in IPAS learning.

RESEARCH RESULTS AND DISCUSSION

Results

Media Feasibility Based on Expert Validation

The validation results showed that the developed AR learning media was categorized as "Very Feasible" by both media experts and subject matter experts. The assessment covered visual design, usability, interactivity, content accuracy, and suitability for elementary school students.

Table 1. Media Expert Validation Results

No.	Aspect of Assessment	Validator	Validator	Average (%)
		1 (%)	2 (%)	
1	Visual Appearance and Design	90	87	88.5
2	Ease of Use (Usability)	88	86	87.0
3	Quality of 3D Animation	91	89	90.0
4	Interactivity	87	85	86.0
5	Suitability for Elementary School Students	89	88	88.5
Overall Average		89.0	87.0	88.5
Category		Very Feasible		

Based on Table 1, the media validation results produced an overall average score of 88.5%, which falls into the "Very Feasible" category. The highest score was obtained in the quality of 3D animation aspect (90.0%), while the lowest score was found in the interactivity aspect (86.0%).

Table 2. Material Expert Validation Results

No.	Aspect of Assessment	Validator 1	Validator 2	Average (%)
		(%)	(%)	
1	Alignment with the Merdeka Curriculum	86	84	85.0
2	Scientific Accuracy of Concepts	88	87	87.5
3	Depth of Material	83	82	82.5
4	Suitability for Students' Cognitive Level	85	84	84.5

5	Relevance to Daily Life	87	86	86.5
	Overall Average	85.8	84.6	85.2
	Category			Very Feasible

Table 2 shows that the subject matter validation also resulted in a “Very Feasible” category, with an overall average score of 85.2%. The highest score was obtained in the scientific accuracy aspect (87.5%), while the lowest score was found in the depth of material aspect (82.5%).

Effectiveness of AR Media in Improving Conceptual Understanding

The effectiveness of the AR learning media was measured through pretest and posttest scores administered before and after the learning intervention. The results are presented in Table 3.

Table 3. Students’ Conceptual Understanding Results

Description	Pretest	Posttest	N-Gain
Lowest Score	45	68	—
Highest Score	80	97	—
Mean Score	61.3	82.7	0.55
Standard Deviation	9.87	7.43	—
N-Gain Category	—	—	Moderate

The results in Table 3 show an increase in students’ conceptual understanding after using the AR learning media. The mean score increased from 61.3 in the pretest to 82.7 in the posttest. The N-Gain score was 0.55, which is categorized as moderate. In addition, the paired-samples t-test showed a statistically significant difference between pretest and posttest scores ($t = 14.62$, $p < .05$).

Student Responses Toward AR Learning Media

Students’ responses to the developed AR media were measured using a questionnaire covering five aspects: ease of use, visual attractiveness, learning motivation, ease of understanding the material, and satisfaction with the learning experience. The results are presented in Table 4.

Table 4. Student Response Results

No.	Aspect	Score (%)	Category
1	Ease of Use	90.8	Very Positive

2	Visual Attractiveness	92.1	Very Positive
3	Learning Motivation	93.7	Very Positive
4	Ease of Understanding the Material	90.9	Very Positive
5	Learning Experience Satisfaction	89.9	Very Positive
Overall Average		91.4	Very Positive

The results in Table 4 show that students gave a very positive response to the AR learning media, with an overall average score of 91.4%. The highest score was obtained in the learning motivation aspect (93.7%), while the lowest score was found in the learning experience satisfaction aspect (89.9%).

The students' comments and technical observations are summarized in Table 5.

Table 5. Selected Student Comments and Technical Notes

Type of Feedback	Student Response / Observation
Positive Comment 1	"I can see the planets moving like real objects."
Positive Comment 2	"Learning IPAS becomes more enjoyable."
Positive Comment 3	"I want to learn again using this application."
Technical Note	Some students reported that the application was less stable on low-specification devices.

Table 5 shows that students responded positively to the application and expressed interest in using it again. However, some technical limitations were reported, especially on devices with lower specifications.

Overall, the findings indicate that the developed IPAS-AR learning media was validated as very feasible by experts, produced a moderate improvement in students' conceptual understanding, and received very positive responses from students.

Discussion

The findings of this study demonstrate that the Augmented Reality (AR)-based learning media developed for Integrated Science and Social Studies (IPAS) instruction is valid, practical, and effective in improving elementary school students' conceptual understanding. The validation results from media experts and subject matter experts indicated that the developed application met the criteria of a highly feasible instructional medium. These findings suggest that the integration of three-dimensional visualization,

interactive features, and curriculum-aligned content successfully fulfilled both pedagogical and technological requirements for elementary school learning.

The high feasibility scores obtained from media experts indicate that the visual design, usability, and interactivity of the developed application were appropriate for the characteristics of elementary school students. The quality of visualization is particularly important because AR technology relies heavily on the ability to present abstract objects in a concrete and observable form. In the context of solar system learning, the three-dimensional representation of planets, planetary movements, and eclipse phenomena enabled students to observe scientific concepts that are otherwise difficult to visualize through conventional instructional materials. This finding is consistent with Garzón et al. (2021), who argued that realistic visualization is one of the main factors contributing to the effectiveness of AR-based learning environments. Similarly, Cabero-Almenara et al. (2023) reported that interactive visual representations in AR applications significantly improve learners' comprehension and engagement because students can directly interact with learning objects.

The positive evaluation provided by subject matter experts further indicates that the learning content was scientifically accurate and aligned with the learning outcomes of the Merdeka Curriculum. This finding supports the view that educational technology should not only emphasize technological innovation but also ensure pedagogical relevance and curriculum integration. According to Manisha and Gargrish (2023), the effectiveness of AR-based learning media depends largely on how well the technology is integrated into instructional objectives and learning activities. Therefore, the feasibility results obtained in this study suggest that the developed AR media possesses both technological quality and educational value.

One of the most important findings of this study is the significant improvement in students' conceptual understanding after using the AR learning media. The increase in posttest scores and the moderate N-Gain value indicate that the developed media successfully facilitated students' understanding of solar system concepts. This improvement may be explained by the unique characteristics of AR technology, which combines virtual and real-world environments to create immersive learning experiences. Through direct interaction with three-dimensional virtual objects, students were able to explore planetary

structures, rotational movements, revolutions, and eclipse processes in a more meaningful way.

The effectiveness of AR in improving conceptual understanding can be explained through Mayer's (2021) Cognitive Theory of Multimedia Learning. The theory proposes that meaningful learning occurs when learners process information through multiple channels, particularly visual and verbal channels, and actively integrate the information into coherent mental models. In the present study, students received information through text, narration, animation, and interactive three-dimensional visualizations simultaneously. Such multimodal presentation helped students reduce misconceptions and develop more accurate conceptual representations of astronomical phenomena.

The findings also support previous studies demonstrating the positive impact of AR on science learning. Hwang et al. (2022) found that AR-based instruction significantly improved students' conceptual understanding because the technology enables learners to connect theoretical explanations with visual representations of scientific phenomena. Likewise, Yilmaz et al. (2024) reported that students exposed to AR learning environments achieved better conceptual understanding and knowledge retention than students taught through traditional methods. The results of the current study reinforce these findings and provide additional evidence that AR can effectively support conceptual learning in elementary school settings.

Furthermore, the improvement in conceptual understanding can be interpreted from a constructivist learning perspective. Constructivist theory emphasizes that knowledge is actively constructed through interaction with the learning environment rather than passively received from teachers. The AR application developed in this study allowed students to manipulate virtual objects, observe dynamic processes, and explore learning materials independently. Such learning experiences encourage active cognitive engagement and facilitate knowledge construction through exploration and discovery. Consequently, students were able to develop a deeper understanding of scientific concepts compared to traditional teacher-centered instruction.

Another important finding concerns students' responses toward the developed AR learning media. The very positive responses obtained from the questionnaire indicate that students perceived the application as attractive, easy to use, and beneficial for learning. The highest score was found in the motivation aspect, suggesting that AR technology effectively

increased students' interest and enthusiasm for learning IPAS. This finding is particularly important because motivation plays a crucial role in determining learning engagement and academic achievement.

The increase in learning motivation observed in this study is consistent with the findings of Alzahrani et al. (2023), who reported that AR environments stimulate students' curiosity and attention through immersive learning experiences. Unlike conventional instructional approaches that rely heavily on textual explanations, AR provides interactive and visually rich learning experiences that capture students' interest and sustain their attention throughout the learning process. Nelson and Gabbard (2024) further explained that AR encourages intrinsic motivation because learners actively participate in exploring and manipulating learning content rather than merely receiving information passively.

The positive comments provided by students also indicate that the developed media succeeded in creating meaningful learning experiences. Students reported that they could observe planetary movements more clearly and found learning activities more enjoyable. These responses reflect the ability of AR technology to bridge the gap between abstract scientific concepts and students' concrete learning experiences. Such findings are consistent with Cabero-Almenara et al. (2023), who concluded that AR-based learning environments significantly improve students' enjoyment, engagement, and satisfaction, which in turn contribute to better learning outcomes.

Despite these positive findings, several limitations were identified during implementation. Some students experienced technical issues when operating the application on low-specification mobile devices. This limitation highlights the importance of technological infrastructure in supporting the successful implementation of AR-based learning. Similar challenges have been reported by Graser and Böhm (2024), who identified device compatibility and system performance as major barriers to the widespread adoption of AR technology in educational settings. Future development should therefore focus on optimizing application performance to ensure broader accessibility across different device specifications.

The findings of this study contribute to the growing body of literature on AR-based learning in elementary education. More importantly, this study addresses several gaps identified in previous research. While many earlier studies focused on learning motivation and academic achievement, the present study specifically examined conceptual

understanding as the primary learning outcome. Furthermore, unlike previous studies that mainly investigated AR in science education, this research developed AR learning media within the context of Integrated Science and Social Studies (IPAS), a distinctive subject introduced through the Merdeka Curriculum. Therefore, this study provides empirical evidence regarding the effectiveness of AR-based learning media in supporting conceptual understanding within integrated elementary school learning environments.

Overall, the results indicate that the developed IPAS-AR learning media represents an effective instructional innovation capable of enhancing students' conceptual understanding, learning motivation, and engagement. The integration of interactive visualization, curriculum-relevant content, and student-centered learning experiences makes AR a promising educational technology for supporting the implementation of the Merdeka Curriculum in elementary schools.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study aimed to develop and evaluate an Augmented Reality (AR)-based learning medium, namely IPAS-AR, to improve elementary school students' conceptual understanding of the solar system topic in Integrated Science and Social Studies (IPAS) learning. The findings indicate that the development process based on the ADDIE model successfully produced an interactive learning application featuring three-dimensional visualization of planets, simulations of Earth's rotation and revolution, eclipse phenomena, and interactive learning activities that support students' exploration of scientific concepts.

The validation results demonstrated that the developed learning media achieved a very high level of feasibility. Media experts rated the product at 88.5%, while subject matter experts provided a score of 85.2%, both categorized as "Very Feasible." These findings suggest that the application meets the requirements of effective educational media in terms of visual design, usability, interactivity, content accuracy, and alignment with the Merdeka Curriculum.

Furthermore, the implementation results revealed that the AR learning media effectively improved students' conceptual understanding. Students' average scores increased substantially from the pretest to the posttest, accompanied by a moderate N-Gain score and a statistically significant difference between learning outcomes before and after

the intervention. These results indicate that the integration of Augmented Reality technology can facilitate the visualization of abstract scientific concepts and support deeper conceptual learning among elementary school students.

The study also found that students responded very positively to the use of AR-based learning media. High levels of motivation, engagement, and satisfaction were observed during the learning process, suggesting that AR technology can create more meaningful, enjoyable, and student-centered learning experiences. Therefore, the findings provide empirical evidence that AR-based learning media can serve as an effective instructional innovation for supporting conceptual understanding and enhancing learning quality in elementary education.

From a theoretical perspective, this study contributes to the growing body of literature on technology-enhanced learning by providing evidence that AR-based instruction supports conceptual understanding through interactive visualization and experiential learning. From a practical perspective, the study offers an alternative learning medium that can assist teachers in implementing innovative and technology-integrated instruction within the framework of the Merdeka Curriculum.

Recommendations

Based on the findings of this study, several recommendations can be proposed. First, elementary school teachers are encouraged to integrate AR-based learning media into IPAS instruction, particularly for topics involving abstract concepts that require visualization and interactive exploration. The use of AR can enrich learning experiences and facilitate students' conceptual understanding more effectively than conventional instructional methods.

Second, schools and educational stakeholders should provide adequate technological infrastructure and professional development opportunities to support the implementation of AR-based learning in classroom settings. Successful integration of educational technology requires not only access to devices but also teachers' digital competencies and pedagogical readiness.

Third, future researchers are encouraged to expand the development of AR learning media to other IPAS topics and different educational levels. Future studies may also incorporate additional features such as adaptive learning systems, gamification elements,

artificial intelligence integration, and collaborative learning activities to enhance learning effectiveness.

Finally, future research should employ more rigorous experimental designs, such as quasi-experimental or randomized controlled trials, involving larger and more diverse samples. Such studies would provide stronger empirical evidence regarding the effectiveness of Augmented Reality in improving conceptual understanding, learning achievement, motivation, and other educational outcomes in elementary education.

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