



The Effectiveness of Augmented Reality on Students' Higher Order Thinking Skills (HOTS) in Geography

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Article History:

Received: Nov 21, 2024

Revised: Dec 02, 2024

Accepted: Dec 25, 2024

Online First: Jan 22, 2025

Keywords:

Augmented Reality,
Higher Order Thinking
Skills,
Solar System Material.

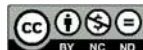
Kata Kunci:

Augmented Reality,
Kemampuan Berpikir Kritis,
Materi Sistem Tata Surya.

How to cite:

Ansori, I., Arianto, F., & Khotimah, K. (2025). The Effectiveness of Augmented Reality on Students' Higher Order Thinking Skills (HOTS) in Geography. *Edunesia : Jurnal Ilmiah Pendidikan*, 6(1), 448-464.

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Abstract: This study examines the effect of using Augmented Reality (AR) on improving students' higher-order thinking Skills (HOTS) in the Solar System material at a high school in Surabaya. HOTS includes critical thinking, problem-solving, and logical reasoning skills essential in 21st-century learning. The study uses a pre-experimental design with a one-group pretest-posttest design. Tenth-grade students were selected through purposive sampling and were given multiple-choice tests before and after the AR-based learning intervention to measure their improvement in HOTS. The results show a significant increase in students' HOTS, with an N-gain score of 0.58, which falls into the moderate category. Statistical analysis revealed a significant difference between the pre-test and post-test scores, indicating that AR effectively enhances students' ability to analyze, solve problems, and express their thoughts more clearly and systematically. These findings imply that the application of AR in learning can support an outcome-based education approach. Integrating AR into the curriculum is expected to improve the quality of learning, support the achievement of educational goals, and develop students' critical thinking skills for their future.

Abstrak: Penelitian ini bertujuan untuk mengkaji pengaruh penggunaan Augmented Reality (AR) terhadap peningkatan kemampuan berpikir tingkat tinggi (Higher Order Thinking Skills/HOTS) siswa pada materi tata surya di salah satu SMA di Surabaya. HOTS mencakup kemampuan berpikir kritis, pemecahan masalah, dan penalaran logis yang sangat diperlukan dalam pembelajaran abad 21. Penelitian ini menggunakan desain eksperimen pra-eksperimental dengan desain pretest-posttest satu kelompok. Siswa kelas X dipilih secara purposive sampling dan diberikan tes pilihan ganda sebelum dan setelah intervensi pembelajaran berbasis AR untuk mengukur peningkatan HOTS mereka. Hasil penelitian menunjukkan adanya peningkatan signifikan pada HOTS siswa dengan nilai N-gain sebesar 0,58, yang tergolong dalam kategori sedang. Analisis statistik mengungkapkan adanya perbedaan yang signifikan antara skor pretest dan posttest, yang menunjukkan bahwa AR secara efektif meningkatkan kemampuan siswa dalam menganalisis, memecahkan masalah, dan menyampaikan pemikiran secara lebih jelas dan terstruktur. Implikasi dari temuan ini adalah bahwa penerapan AR dalam pembelajaran dapat mendukung pendekatan pendidikan berbasis hasil (outcome-based education). Integrasi AR di dalam kurikulum diharapkan dapat meningkatkan kualitas pembelajaran dan membantu pencapaian tujuan pendidikan yang lebih baik, serta mengembangkan keterampilan berpikir kritis siswa untuk masa depan mereka.

A. Introduction

Higher Order Thinking Skills (HOTS) has become a pivotal focus in the Merdeka Curriculum of Indonesia, reflecting the national commitment to equipping students with the skills needed to navigate an increasingly complex global landscape. HOTS emphasizes the development of competencies such as critical, creative, and innovative thinking, collaboration, and self-confidence (Sholeh et al., 2024). These skills are foundational for academic success and essential for fostering adaptability and problem-solving abilities in real-world contexts. This focus aligns with global educational standards, as underscored by international assessments like the Programme for International Student Assessment (PISA). However, Indonesia's performance in PISA remains a critical concern. Despite slight improvements in the 2022 results, the nation ranks 74th out of 79 participating countries in reading, mathematics, and science (Bilad et al., 2024). Such rankings underscore the persistent challenges in the quality of Indonesia's education system, particularly in developing students' ability to think critically and solve problems effectively.

The urgency of addressing these challenges is heightened by Indonesia's aspirations to compete globally, where innovative and critical thinking has become a cornerstone for success. Despite the Merdeka Curriculum's emphasis on HOTS, many Indonesian students struggle to master these skills due to entrenched traditional teaching practices. These approaches often prioritize rote memorization over deeper conceptual understanding, leaving students ill-equipped to engage in higher-order cognitive tasks, such as analysis, evaluation, and creation (Pinasthi et al., 2024). This gap is especially pronounced in subjects that require abstract or complex conceptual understanding, such as geography. In high schools across Surabaya, for example, students' low performance in HOTS-based assessments highlights the inadequacy of current teaching methodologies. Teachers frequently cite the lack of active learning strategies and limited exposure to HOTS-focused training as significant barriers to fostering these skills.

Innovative and active learning methodologies that prioritize student engagement and experiential learning are crucial to bridge this gap. Theoretical frameworks on cognitive learning, such as those proposed by Anderson & Krathwohl (2001), emphasize that HOTS can be cultivated through active, hands-on experiences, including observation, critical analysis, problem-solving, and application of knowledge. Such approaches allow students to acquire information and evaluate, synthesize, and apply it in novel contexts. In this context, augmented reality (AR) is a promising tool for enhancing HOTS. AR technology seamlessly integrates real and virtual environments, enabling users to interact with three-dimensional objects in real-time (Miyanti et al., 2024). This interactive medium allows students to explore complex and abstract concepts more tangibly and engagingly, fostering more profound understanding and retention.

Applications such as Assemblr Edu exemplify the potential of AR in educational settings. These tools allow students to visualize and manipulate 3D objects, making learning more dynamic and relatable. For instance, instead of relying on static images or text to teach topics like the solar system, AR enables students to explore planetary structures and

movements interactively, promoting a richer conceptual understanding (Pamorti & Suryandari, 2024). This immersive experience can help students bridge the gap between theoretical knowledge and practical application, enhancing critical thinking and creativity.

Despite the growing body of research highlighting the general benefits of AR in education, significant gaps remain in its application to specific subject areas, such as geography. While studies have demonstrated AR's effectiveness in boosting engagement and understanding in subjects like natural sciences and mathematics, its impact on geographical education, particularly in fostering HOTS, remains underexplored. Moreover, existing research often focuses on student engagement and comprehension, with limited attention to AR's direct influence on higher-order cognitive skills such as analysis, evaluation, and creation. These gaps present a critical opportunity for innovation and advancement in the field.

This study seeks to address these gaps by investigating the unique potential of AR to enhance HOTS in the context of geography education in Indonesia. The research focuses specifically on the solar system topic, requiring students to grapple with abstract concepts and spatial reasoning. The novelty of this study lies in its integration of AR technology with a HOTS-oriented approach, offering a fresh perspective on how digital tools can transform traditional learning practices. By doing so, this research contributes to the theoretical understanding of AR in education and provides practical insights for its implementation in the classroom.

The significance of this study extends beyond the immediate context of geography education. In the 21st century, digital literacy and technological problem-solving skills have become essential components of education worldwide. As Putra et al (2024) emphasize, the ability to use, evaluate, and innovate with digital tools is critical for preparing students to face global challenges. The integration of AR into learning environments enhances comprehension of complex concepts and fosters critical thinking, creativity, and adaptability – indispensable competencies in a rapidly evolving world.

In light of these considerations, this study aims to evaluate the effectiveness of AR technology in enhancing HOTS among high school students in Surabaya, particularly in the context of learning about the solar system in geography education. The general objective is to explore the potential of AR in improving the quality of geography education through a HOTS-oriented approach. Specifically, this study seeks to analyze the impact of AR technology on students' conceptual understanding of the solar system, evaluate its effectiveness in enhancing critical thinking and creativity, and assess the extent to which AR increases student engagement and active participation in learning activities.

This research aims to provide evidence-based recommendations for integrating AR into geography education by addressing these objectives. The findings will contribute to the broader goal of improving educational quality in Indonesia, offering a model for leveraging technology to foster higher-order cognitive skills and prepare students for the complexities of the modern world.

B. Method

This study adopts a pre-experimental design, specifically a one-group pretest-posttest design, as Sugiyono (2015) outlined. This methodological approach involves administering a test to a single group of students both before and after an intervention to measure the effect of the intervention on the dependent variable. While it lacks the inclusion of a control group for comparison, this design effectively highlights changes in outcomes within the same group, providing initial insights into the effectiveness of the intervention – in this case, Augmented Reality (AR) technology in enhancing higher-order thinking Skills (HOTS). Here is the flow of the One-group pretest-posttest design, as illustrated in Figure 1.

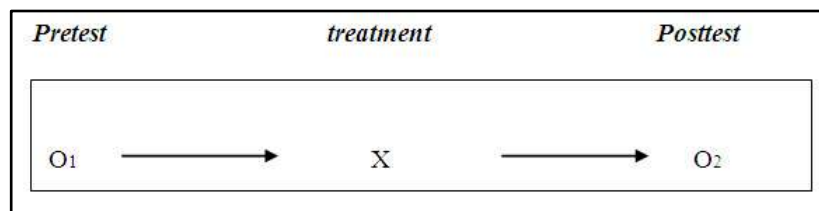


Figure 1. The Flow of the One-Group Pretest-Posttest Design

Remarks :

O1 : Pre-test before treatment

O2 : Post-test after treatment

X : Treatment

The population of this study comprises 10th-grade students at a high school in Surabaya during the 2024/2025 academic year. A purposive sampling technique was employed to select a sample of 30 students, ensuring that participants met specific criteria relevant to the study objectives. As described by Sugiyono (2015), Purposive sampling allows researchers to focus on a subset of the population that is most likely to provide meaningful and relevant data for the research questions.

This research flow outlines the steps in evaluating the effectiveness of Augmented Reality (AR)-based learning media for class X-2 students at a high school in Surabaya. Each step in the process, from identifying the subject to concluding, has been systematically planned to ensure the validity and reliability of the findings. Below is a detailed explanation of each stage in the research flow.



Figure 2. Research Flow

1. Subject

The research subjects are students from class X-2 at a high school in Surabaya. This class will be the main participants in testing the Augmented Reality (AR)-based learning media.

2. Pre-Test

The students of class X-2 will take a pre-test before the implementation of AR-based media. This test aims to measure their initial abilities or understanding of the material to be studied, such as the Solar System topic. The pre-test data will serve as a baseline for comparing the learning outcomes after using the AR-based media.

3. Implementation of Augmented Reality

In this stage, the AR-based learning media will be implemented for the students of class X-2. This process includes using devices like smartphones or tablets to access the developed AR content. The implementation is carried out by the lesson plan (RPP), which is designed to ensure students understand the material interactively.

4. Post-Test

After completing the AR-based learning, the students of class X-2 will take a post-test. This test aims to measure the improvement in students' understanding after using the AR-based learning media. The results of the post-test will be compared with those of the pre-test.

5. Data Analysis

The data from the pre-test and post-test will be analyzed to evaluate the effectiveness of the AR-based learning media. The analysis will use appropriate statistical methods, such as a mean difference test or other relevant methods. The analysis results will reveal how much the AR media improved the students' understanding in class X-2.

6. Drawing Conclusions

Based on the results of the analysis, the researcher will conclude that AR-based learning media is effective for class X-2 students at a high school in Surabaya. These conclusions will include the main findings, the impact of AR media on learning, and recommendations for further development and use of similar media in the future.

The study utilized a 10-question multiple-choice test to measure HOTS based on [Anderson & Krathwohl \(2001\)](#) taxonomy, explicitly targeting the following cognitive processes: analyzing (C4), evaluating (C5), and creating (C6). Each question was designed to align with these higher-order cognitive processes, challenging students to go beyond memorization and engage in deeper thinking. The test underwent rigorous validation processes, including reliability testing, which yielded a coefficient of 0.74 (indicating good reliability), a standard deviation of 3.86, and an XY correlation of 0.59. These metrics confirm that the test items are consistent and can measure the intended constructs.

The implementation phase of the study was conducted in September 2024. During this phase, students were introduced to learning materials through Augmented Reality (AR) media, facilitated by the Assemblr Edu application. This platform was chosen because it can visualize three-dimensional concepts interactively, enabling students to engage with the

material in ways that static text and images cannot achieve. For example, students could dynamically explore the solar system's components—planets, moons, and other celestial objects—and their interactions, fostering a more immersive and engaging learning experience.

To accommodate students' schedules and technological accessibility, the learning sessions were conducted online. Video conferencing through Google Meet served as the primary medium for delivering instruction. At the same time, Google Forms was used to administer pre-tests and post-tests, ensuring seamless and efficient data collection. This hybrid approach reflects the increasing integration of technology in education, aligning with the goals of the Merdeka Curriculum and Indonesia's broader push for digital literacy.

The test questions were meticulously designed to align with the Rencana Pelaksanaan Pembelajaran (RPP) and the associated Basic Competency (Kompetensi Dasar) 3.10, which emphasizes analyzing relationships within the solar system. This competency involves understanding and mapping the connections between celestial objects—such as planets, moons, and the sun—and the phenomena that govern their interactions, including rotation, revolution, and gravitational forces. For example, students were tasked with analyzing how gravitational pull influences planetary orbits or how the rotation of planets affects day and night cycles.

The competence indicators were designed to develop student's analytical abilities, particularly in identifying and mapping relationships between astronomical phenomena. Table 1 outlines the specific indicators used in the study, showcasing how they align with the objectives of enhancing HOTS through AR technology. These indicators include evaluating celestial objects' interdependence and creating conceptual models that illustrate their interactions. By integrating AR into the learning process, students were exposed to theoretical knowledge and allowed to engage with practical applications, bridging the gap between abstract concepts and real-world understanding.

Overall, this research design reflects a systematic and technology-enhanced approach to addressing challenges in HOTS development. By leveraging AR and aligning instructional materials with curriculum standards, the study seeks to provide valuable insights into innovative educational practices that could transform learning outcomes in Indonesian schools. The indicators of competence achievement aim to develop student's analytical skills in mapping and connecting various concepts in astronomy, as shown in Table 1.

Table 1. Learning Indicators

Learning Indicators
1. Analyzing the position and movement of planets in the solar system.
2. Relating the movement of planets to natural phenomena that occur.
3. Interpreting the influence of gravitational forces in the solar system.
4. Concluding simple experiments about the movement of celestial bodies.
5. Designing simple experiments to model the movement of planets in the solar system.

The question grid for Higher Order Thinking Skills (HOTS), which covers the abilities to analyze, evaluate, and create, can be found in Table 2.

Table 2. Exam Framework

No.	HOTS Indicators	Number of Question	Total Questions
1	Analytical Skills	1,4,5,6,9	5
2	Evaluative Skills	2,3,7	3
3	Creative Skills	8,10	2
Total			10

C. Result and Discussion

Result

Higher-order thinking Skills (HOTS) involve more complex cognitive processes such as analysis, evaluation, and synthesis. These skills enable students to go beyond simple memorization and apply their knowledge meaningfully. Developing HOTS is essential for students to succeed in academic and real-world settings.

According to [Abraham et al \(2021\)](#), HOTS involves various higher cognitive aspects, ranging from organizing and breaking down material, drawing conclusions, and creating representations of ideas or concepts to developing correlations between existing knowledge. These skills enable students to think deeply, tackle problems more creatively, and produce effective solutions in complex situations.

[Walid et al \(2019\)](#) add that HOTS can be developed through a learning process that involves questions oriented toward higher-order thinking. Such questions assess knowledge and test students' abilities to analyze and critically solve problems. HOTS-oriented questions typically involve various forms of representation, such as images, graphs, tables, or texts, which require students to process information more deeply.

Active learning approaches like problem-solving, project-based, and inquiry-based learning are crucial to developing HOTS. These methods allow students to apply their knowledge to real-world situations, fostering more profound understanding and higher-level thinking skills. In this context, the use of technology, such as Augmented Reality (AR) and Artificial Intelligence (AI), can offer students a more interactive and immersive experience while also supporting cognitive reinforcement in processing information ([Zuniari et al., 2022](#)).

By involving various visual aids and more complex data representations, students can be challenged to make connections between concepts they have not encountered before. This can enhance their analytical and critical thinking abilities, which are at the core of HOTS. For example, in geography or science education, students can be encouraged to analyze natural phenomena using data from graphs or tables and link them with existing theories, thereby deepening their understanding.

In addition, HOTS evaluation should not be limited to final exams but also include more frequent formative assessments, allowing students to be trained in critical thinking at

every stage of their learning. Therefore, developing HOTS requires a combination of effective teaching methods and technology that supports more profound and comprehensive learning (Sumarni & Badruzsaufari, 2020). Research suggests that Augmented Reality (AR) media, specifically the Assemblr Edu application, can improve students' higher-order thinking skills (HOTS). This was determined through assessments based on the HOTS indicators proposed by Anderson & Krathwohl (2001), which include remembering, understanding, applying, analyzing, evaluating, and creating.

The test results show that after learning to use AR media, students experienced significant improvement in their ability to analyze information, make accurate decisions, and generate creative solutions to the given problems. The more interactive learning process through AR technology provided students with a more profound experience. It allowed them to see and interact with concepts that were difficult to understand through traditional methods (Bhakti et al., 2019).

The results of this study can be visualized in the graph presented in Figure 2, which illustrates the improvement in students' HOTS scores after participating in learning supported by the Assemblr Edu application. The graph compares the scores before and after learning with AR, showing significant progress in analysis, evaluation, and creation.

This highlights that technology, particularly Augmented Reality, can effectively support learning focused on developing HOTS. By providing visual and interactive representations of learning materials, students can more easily understand complex concepts and practice their critical thinking skills in more real-world and relevant situations (Havita et al., 2021).

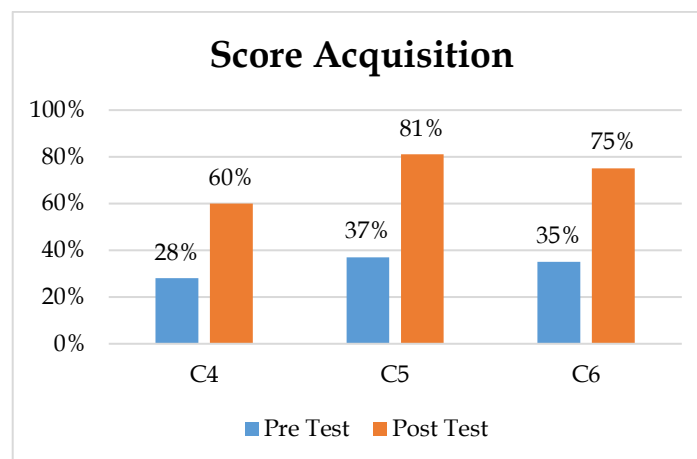


Figure 3. Score Acquisition

As shown in Figure 2, the results reveal a significant difference between the pre-test and post-test scores following the implementation of AR-based learning. This demonstrates that Augmented Reality (AR) media positively influences students' higher-order thinking Skills (HOTS). The marked improvement in scores highlights AR's ability to enhance students' understanding and application of complex concepts, particularly in areas such as analysis, evaluation, and creation, which are critical components of HOTS.

Students exposed to AR-based learning showed notable progress in thinking critically and solving problems creatively. The interactive nature of AR enables students to engage with 3D models and simulations, making abstract concepts more tangible and easier to grasp. This dynamic learning experience promotes active engagement and fosters curiosity as students explore and interact with material in ways that traditional methods often fail to achieve.

These findings underscore the transformative potential of AR in education. By providing immersive, hands-on learning opportunities, AR strengthens cognitive skills and prepares students for real-world applications of their knowledge. This study contributes to the growing evidence that integrating AR into classrooms can effectively enhance critical thinking and problem-solving skills, making it a valuable tool in modern education.

The significant N-gain of 0.71 indicates AR media's high effectiveness in boosting learning outcomes and enhancing content comprehension and higher-order thinking skills.

Table 3 provides a detailed breakdown of the N-gain calculations for each student, demonstrating a significant improvement in student achievement between the pre-test and post-test. This high N-gain value highlights the effectiveness of AR media, like Assembly Edu, in enhancing students' higher-order thinking skills and their potential as a valuable learning tool.

Table 3. The Result of N-gain Test

Data	Average N-gain	Category
Pre-Test and Post-Test Scores	0.58	Moderate

Next, a normality test was conducted on the average pre-test and post-test scores. The results of this normality test are presented in Table 4.

Table 4. Normality Test

	Shapiro-Wilk		
	Statistic	df	Sig.
Pre-test	,950	30	,173
Post-test	,952	30	,193

a. Lilliefors Significance Correction

Based on the Shapiro-Wilk test, the Asymp. Sig. Values for the pre-test and post-test data exceed α (0.05), suggesting that the data is usually distributed. Subsequently, a homogeneity test was conducted to assess data homogeneity. The results of the homogeneity test are summarized in Table 5.

Table 5. Test of Homogeneity

Levene Statistic	df1	df2	Sig.
2,045	4	24	,120

Levene's test for homogeneity of variances yielded a significance value of 0.120, more significant than α (0.05). This indicates that the data is homogeneous. Given the normal distribution and homogeneity of the data, a Paired-Sample T-test was conducted. The results of this test are presented in Table 6.

Table 6. Hypothesis Testing with Paired-Sample Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre - Post	-43,667	14,499	2,647	-49,081	-38,253	-16,495	29	,000

The Paired-Sample T-test analysis revealed a statistically significant difference between the pre-test and post-test scores, with a p-value of 0.000, well below the established significance level of 0.05. This outcome indicates that Augmented Reality (AR) media considerably enhances students' higher-order thinking Skills (HOTS). The results provide clear evidence that integrating AR in the learning process led to a notable improvement in students' cognitive abilities, particularly in tasks involving analysis, evaluation, and creation, which are central to HOTS.

The research findings further demonstrate a significant improvement in student performance, as shown by the marked increase in post-test scores compared to the pre-test scores. This enhancement in learning outcomes can be attributed directly to introducing AR as a teaching tool. Using AR, students could interact with three-dimensional representations of the solar system, providing a more tangible and immersive understanding of complex astronomical concepts. For instance, students could manipulate 3D models of planets, moons, and other celestial bodies, observing their movement and interactions dynamically, which traditional 2D visuals could not offer. This hands-on, visual learning experience strengthened their comprehension and fostered critical thinking by allowing students to engage with the material in ways that prompted deeper inquiry and exploration.

As Handoyono (2020) suggested, incorporating innovative learning media, such as AR, can significantly enhance educational outcomes by promoting active learning and encouraging greater student engagement. AR's ability to offer interactive experiences helps bridge the gap between theoretical knowledge and practical application, enabling students

to better grasp abstract concepts by visualizing them in real time. AR also facilitates more effective communication between teachers and students, as it allows for immediate feedback and clarification of complex ideas, further supporting the learning process.

In contrast, the pre-test scores reflect the students' initial understanding of the solar system based on their prior knowledge before the intervention with AR technology. These scores serve as a baseline, showing students' understanding of the topic before being exposed to the enhanced learning experience. The significant improvement in post-test scores underscores the effectiveness of AR in enhancing students' ability to think critically and creatively, ultimately leading to better retention of knowledge and application of concepts learned.

Overall, the study highlights the potential of Augmented Reality as an effective educational tool, particularly in enhancing higher-order thinking skills. By providing an interactive and engaging learning environment, AR helps students understand complex concepts more profoundly and empowers them to apply their knowledge in innovative and meaningful ways. This research contributes to the growing body of evidence supporting the use of AR in educational settings and emphasizes the importance of incorporating technology to foster 21st-century skills in students.

Discussion

Based on the graph shown in Figure 2, the post-test scores for questions at the C4 level (analyzing) show an improvement with a percentage of 60%, which falls into the "adequate" category. There was an improvement in the C5 level questions (evaluation), with a percentage of 81%, which falls into the "very good" category. For the C6 level questions (creating), there was an improvement with a percentage of 75%, which falls into the "good" category.

The C4 level questions (analyzing) train students to break down the solar system material into parts and understand how those parts are connected to the overall structure or goal. The C5 level questions (evaluating) train students to make judgments based on specific criteria or standards. Meanwhile, the C6 level questions (creating) train students to combine elements into a functional whole and reorganize those elements into a new pattern or structure (Abraham et al., 2021).

The question levels were designed to align with Anderson & Krathwohl (2001) knowledge dimensions, including factual, conceptual, procedural, and metacognitive knowledge. Factual knowledge pertains to essential information, such as planet names and characteristics. Conceptual knowledge involves understanding the relationships between concepts like planetary order and size. Procedural knowledge relates to skills and techniques like using a telescope or analyzing astronomical data. Metacognitive knowledge refers to awareness of one's thinking and learning processes, such as planning strategies or evaluating understanding. By addressing these dimensions, the AR-based learning experience fosters a deeper and more comprehensive understanding of the solar system (Fitri et al., 2024).

Aligned with Anderson and Krathwohl's taxonomy, HOTS questions effectively assess students' higher-level thinking skills, specifically in analysis, evaluation, and synthesis. By engaging with complex material and problem-solving, students can develop more profound understanding and critical thinking abilities (Panwar et al., 2024). Research suggests augmented reality (AR) technology can significantly enhance students' higher-order thinking skills. In solar system learning, AR has improved students' performance in analysis, evaluation, and creative thinking (Gallardo et al., 2022). This indicates that AR can be a powerful tool for fostering more profound learning and critical thinking (Aththibby et al., 2024).

The significant improvement in the C5 (evaluating) and C6 (creating) domains indicates that learning using Augmented Reality media is more effective in training students' abilities to evaluate and create. This is evident in the learning process where the researcher applied the Problem-Based Learning (PBL) model, which connects real-life problems with the solar system material. Linking problems students often face encourages them to explore the material more and sharpen their thinking and problem-solving abilities. Cetintav & Yilmaz (2023) states that Problem-Based Learning (PBL) trains students to conduct investigations by analyzing information, experimenting, and drawing conclusions. In line with this, Wijayanto et al (2023) assert that the Problem-Based Learning (PBL) model encourages students to use higher-order thinking skills, particularly in problem-solving and addressing challenges they face.

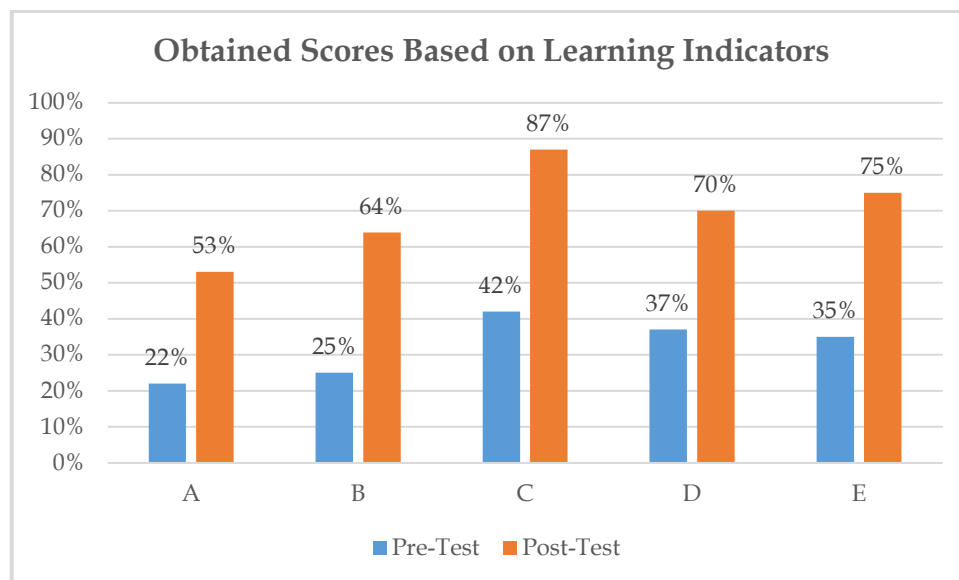


Figure 4. Obtained Scores Based on Learning Indicators

From the perspective of score acquisition based on learning indicators, it is evident that the post-test results are higher than the pre-test, with a significant difference. Indicator C, "interpreting the mechanism of the solar system's operation," shows a higher score than other indicators. While individual student performance varied due to differences in academic abilities, the overall impact of Augmented Reality (AR) learning media, supported

by the Assembly Edu application, significantly improved students' cognitive learning outcomes. Compared to pre-intervention scores, students demonstrated substantial improvement, achieving good and very good results. This indicates that when effectively implemented, AR can be a powerful tool for enhancing student learning.

In Indicator A, "Analyzing the mechanism of the solar system's operation," the results obtained were the lowest compared to the post-test scores on other indicators. However, there was a significant improvement compared to the students' pre-test scores. Indicator A contained story-based questions that trained students to enhance their reading literacy skills. Students' ability to read texts carefully made answering questions easier, thereby measuring their analytical skills. In Indicator B, "Relating lifestyle patterns to solar system phenomena," an improvement in post-test scores compared to pre-test scores was also observed, indicating that students could connect their thoughts with real-life situations.

In Indicator C, "Interpreting the mechanism of the solar system's operation," the highest results were obtained compared to the other indicators. The use of Augmented Reality media in this learning process significantly impacted the development of students' C5 (evaluating) skills. Indicator C, which contained questions in the form of images, made it easier for students to answer the questions. The Assemblr Edu application, used by students during the learning process, provided 3D images that greatly facilitated students in understanding the material being taught.

In Indicator D, Augmented Reality (AR) media in learning the solar system improved students' higher-order thinking skills, specifically in experimentation, conclusion-drawing, and creative thinking. For instance, in indicators D and E, which assessed students' ability to design and conduct experiments and draw conclusions about the solar system, a significant improvement was observed in post-test scores. This suggests that AR media facilitated students' engagement in active learning, enabling them to apply their knowledge and skills practically.

Furthermore, AR's 3D visualization capabilities allowed students to construct mental models of the solar system, promoting creative thinking and problem-solving. This indicates that AR can effectively stimulate students' higher-order thinking skills, improving learning outcomes. In this study, the use of Augmented Reality media had a positive impact on improving students' learning outcomes, particularly with the application of Assemblr Edu, which displayed 3D images that facilitated the understanding of the solar system's structure. As Pamorti, O. A. explains, virtual media gives students a new perspective on studying science and enhances their digital literacy. This application helps students better understand the learning material, especially abstract concepts like those found in the solar system, which is more easily comprehended through the 3D visualizations provided by Assembly Edu (Sagayam et al., 2020). The design of the Augmented Reality application can also spark students' interest in delving deeper into the subject matter (Ervana et al., 2024). Additionally, the accessibility of Augmented Reality (AR) learning media through the Assemblr Edu app, which can be downloaded onto smartphones, empowers students to take an active role in

their learning process. By providing hands-on experiences and encouraging observation, AR can significantly enhance students' higher-order thinking Skills (HOTS).

Therefore, the combination of Augmented Reality (AR) media and Problem-Based Learning (PBL) is highly effective in enhancing students' higher-order thinking Skills (HOTS). The Assemblr Edu app, as a specific AR tool, provides students with direct experiences, making learning more engaging and effective. This research suggests that AR media can be a valuable tool for teachers to foster higher-order thinking skills in the classroom. The researcher recommends using Augmented Reality (AR) media, as it aligns with research conducted by Rizki & Suprpto (2024), which indicates that AR can facilitate concept mastery and stimulate creative thinking. Fauziah et al (2024) also highlight that Augmented Reality (AR) can significantly enhance students' focus and engagement in learning.

Furthermore, Rahmayani et al (2024) state that Augmented Reality (AR) can deepen students' understanding, increase motivation, and stimulate creativity. Sakdiah et al (2023) also suggest that Augmented Reality (AR) media can enhance learning outcomes. Therefore, AR can contribute to more effective learning and a deeper understanding of the solar system.

D. Conclusion

Based on the findings, it can be concluded that augmented reality (AR) is an effective tool for enhancing students' higher-order thinking skills (HOTS) in learning about the solar system, particularly in understanding its structure and components. AR is vital in creating interactive and immersive learning experiences that encourage students to think critically and creatively and solve problems more effectively. Thus, AR can be an innovative approach to support HOTS-oriented learning in geography education.

The results of this study indicate that integrating AR into learning improves students' conceptual understanding and positively impacts their engagement and motivation. These findings have significant implications for educators and policymakers who are considering adopting AR in school curricula. By incorporating this technology more broadly, learning can be more relevant to 21st-century demands, which require digital literacy, higher-order thinking skills, and technological changes.

Future research is recommended to explore the application of AR in other learning topics that also require deep conceptual understanding, such as topographic maps or geographical phenomena. Additionally, further studies could focus on evaluating the long-term impact of AR on the development of HOTS, particularly in the aspects of evaluation and creation. Research could also examine the effects of AR on diverse groups of students, including those with low digital literacy, to ensure that the technology is inclusive and effective for all learners.

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