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The Effect of Using Augmented Reality (AR) Assembler to Improve Scientific Explanation and Student Interest in Science Learning

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Abstract

This study aims to analyze the effect of using Augmented Reality (AR) assisted by Assembler in improving the ability of scientific explanation and student interest in learning science. The method used was quasi-experimental with a one-group pretest-posttest design on 20 seventh grade students of SMP Muhammadiyah 3 Depok. Data were collected through scientific explanation ability test and learning interest questionnaire, then analyzed using Paired Sample t-test and Cohen's d to measure the intervention effect. The results showed a significant increase in scientific explanation ability and interest in learning. The highest scientific explanation indicator is in claim, while interest in learning is dominated by aspects of attention and feelings of pleasure. The findings prove that Augmented Reality (AR) is effective as an innovative learning media to improve the understanding of science concepts and students' learning motivation. The implications of the research encourage the integration of Augmented Reality (AR) technology in the science curriculum to create interactive and meaningful learning experiences.

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INTRODUCTION

Education plays a fundamental role in shaping self education and influencing human behavior. The learning process plays a crucial role in shaping self identity, honing critical thinking skills, developing social skills, and preparing a person for future challenges. Education not only functions as a means of transferring knowledge, but also as an agent of social change that can encourage the progress of society as a whole (Fau et al., 2023). Learning systems that were previously teacher-centered and one way in nature are now starting to shift towards a more interactive, collaborative, and technology-based approach (Romadhina & Ruja, 2024).

The Industrial Revolution 4.0 and digital transformation have significantly changed education, especially in response to 21st century competencies that rely on advances in science and technology. Science and technology play an important role in improving human welfare (Purnamasari et al., 2022), while technology integration in education supports more innovative and flexible learning models that increase student engagement and help teachers deliver material more effectively (Candra Dewi et al., 2023).

Learners are not only required to master content, but must also have the ability to think critically, solve problems, and communicate knowledge scientifically. One essential competency that must be fostered is scientific explanation. Scientific explanation enables students to explain natural phenomena logically, systematically, and based on valid scientific evidence (Rojikin et al., 2022). Scientific explanation ability is the ability to construct scientific explanations that involve the use of arguments, facts, and logic to explain scientific phenomena (Wannathai et al., 2024) . Components of scientific explanation consist of three main elements: claim, evidence, and reasoning (Laksmi et al. 2021). Which must be connected coherently to produce meaningful scientific understanding (Supeno et al., 2017). Scientific explanation has five levels that correspond to the success of students in conveying (J.-X. Yao, Liu, and Guo 2023). The level of knowledge of scientific explanation skills is the first level, Identifying phenomena that need to be explained simply, the second level students begin to add support for their statements, the third level students after looking for supporting data and linking the data to the statement in a simple but imperfect manner, the fourth level, students have done the stages perfectly, the fifth level students can develop their scientific explanations more specifically (J. Yao & Guo, 2018). Previous research by Yao (2023) shows that students' scientific explanation skills can be improved through learning progression based instructional designs, indicating the importance of learning approaches that support gradual skill development.

In addition to scientific explanation, students' interest in learning also plays an important role in supporting the success of science learning. High learning interest encourages active participation and enhances students' understanding of scientific concepts that are often perceived as abstract and challenging. Several studies report that students' interest in science learning can be increased through innovative and interactive learning methods, including practicum activities, role-playing, and the use of digital technologies such as Augmented Reality (AR) (Jirout, 2020; Prasetyoningsih et al., 2023; Simanullang et al., 2024; Zega & Harefa, 2024).

Responding to these challenges, the integration of technology-based learning media becomes increasingly important. Technology provides broad access to information sources and supports the development of digital skills and creativity through interactive learning experiences (Silvi, 2023). Empirical evidence also demonstrates that educational technology integration can significantly enhance students' critical thinking literacy, which is a key competency in 21st century education (Wisudojati et al., 2024). Therefore, technology in education should not merely function as a supporting tool but as an integral component of the learning process.

Various digital innovations are beingintegrated to support a more effective and engaging learning process. Technologies such as social media, simulation, educational games, as well as Augmented Reality (AR) and Virtual Reality (VR) offer immersive and interactive learning experiences that can increase students' motivation and understanding of complex learning materials (Yusuf, 2020). Among these innovations, AR has gained increasing attention due to its potential to enhance learning quality. AR integrates virtual objects into the real-world environment in real time, allowing learners to interact directly with digital content within a physical context (Alfitriani et al., 2021; Al-Ansi et al., 2023). This capability enables abstract concepts to be visualized more concretely, facilitating deeper conceptual understanding (Alfitriani et al., 2021; Aprilinda et al., 2022; Aprilia & Suwandayani, 2025).

Augmented Reality (AR) serves as a learning media that can increase motivation, interest, and understanding of students (Chen, 2020). AR is able to present abstract or complex learning materials to be more easily understood through

interactive and multisensorial visualization (Weng et al., 2020). This is proven to encourage the active involvement of students in the teaching and learning process, as well as improve their ability to explain scientific concepts in more depth (Sudharsono et al., 2024). Thus, AR is not only a visual aid, but also a learning medium that can transform the way learners understand and internalize knowledge.

Globally, international research also confirms that AR is one of the key innovations in 21st century education that is driving the transformation of how we learn and teach (Semerikov & Striuk, 2024). AR facilitates the visualization of scientific concepts through projected virtual objects, bridging the gap between abstract theory and real-world understanding (Saputra et al., 2022; Alfarizi & Mahmud, 2024; Amores-Valencia et al., 2023). Despite the growing body of research on AR in education, several gaps remain. Most existing studies focus separately on students' cognitive achievement, motivation, or conceptual understanding, with limited attention to the integration of scientific explanation skills and learning interest simultaneously. Based on observations and interviews with seventh grade science teachers at SMP Muhammadiyah 3 Depok, although various learning models and media have been implemented, AR technology has not yet been applied comprehensively in science learning, particularly in activities that emphasize visualization and explanation skills. Moreover, empirical studies examining the combined effect of AR-based learning media on scientific explanation skills and students' learning interest at the junior secondary level remain limited. This research can expand the scope of other research on augmented reality in science learning.

METHOD

This research uses a quasi-experimental design with a mixed methods approach (quantitative and qualitative). The research design used is more of a one-group pretest- posttest design to measure the complex science concepts that are projected into the real world, so that abstract consepts can be visualized in real terms and are easier to understand (Saputra et al., 2022). The following is the structure of the design.

$$O_1 \rightarrow X \rightarrow O_2 \qquad (1)$$

Description:

O_1 (Pre-test)	:	Measurement of dependent variables (scientific explanation & interest in learning) before treatment
X (Treatment)	:	The use of Augmented Reality (AR) in learning
O_2 (Post-test)	:	Measurement dependent variables after treatment

This study used a sample of one seventh grade class at SMP Muhammadiyah 3 Depok with a total of 20 students. SMP (Junior High School) is the first level of secondary school in Indonesia, equivalent to junior high school, which typically includes students aged 12 to 15 years. Data collection was conducted using interviews with teachers, pretest and posttest questions, and learning interest questionnaires. There are three indicators of scientific explanation (Table 1).

Table 1. Scientific Explanation Indicators

Indicators	Description
Claim	The main statement or answer to the scientific question posed.
Evidence	Data or relevant supporting information to strengthen the claim.
Reasoning	A logical explanation that connects evidence to claims using scientific concepts or principles.

Rubio N & Meneses, (2021)

The indicators of learning interest used in this study were adopted from Arisanti & Subhan (2018), Arliyanty (2017), Lika et al., (2024), and Aswidyaningrat et al., (2024).

Table 2. Learning Interest Indicators

Aspect	Indicators	
Feeling of Happiness	1	Students express their feelings of happiness towards lesson.
	2	Students enjoy doing assignments and exercises.
Student Interest	1	Active in group and class discussions
	2	Answering questions asked by the teacher
Student Engagement	1	Do the task as soon as possible
	2	Taking the initiative to study independently and seek learning resources
Student Attention	1	Take notes on the material presented
	2	Pay attention and listen to the educator's explanation

The indicator of learning interest in this study, namely 1) feeling of happiness, 2) student

interest, 3) student engagement, and 4) student attention. The quantitative data analysis technique used was the Paired Sample t-test and effect size to measure the magnitude of the increase.

Data collection was conducted using interviews with teachers, pre-test and post-test questions, and learning interest questionnaires. The quantitative data analysis technique used was the Paired Sample t-test and effect size to measure the magnitude of the increase. The Paired Sample t-test is designed to determine whether there has been a change or improvement in students' abilities after treatment. The following is the formula for the Paired Sample t-test.

$$t = \frac{\bar{d}}{S_d/\sqrt{n}} \qquad (2)$$

Description:

$\bar{d}$: Mean difference between post-test and pre-test

S_d : Standard deviation of differences

n : Number of samples (data pairs)

Meanwhile, effect size is used to measure the magnitude of the improvement that has occurred. The following is the formula for effect size, based on Cohen's d formula.

$$d = \frac{M_1 - M_2}{SD} \qquad (3)$$

Description:

M_1 : Average of the experimental group (after treatment)

M_2 : Average control group (or before treatment, if pre-post in one group)

SD : Combined standard deviation of two groups

The test results can be interpreted according to the Table 3.

Tabel 3. Interpretation of Cohen's d Results

Interval	Criteria
$0 < X \leq 0.02$	Small
$0.02 < X \leq 0.06$	Medium
$0.06 < X \leq 0.8$	Large
$0.8 < X \leq 1.3$	Very Large

Sullivan & Feinn (2012)

The Cohen's d table illustrates the impact of an intervention on a student's learning achievement. The categories presented are based on Cohen's d values to indicate the strength of the impact (effect size). An effect size is considered small if the interval is between zero and 0.02, indicating that the impact is very minor and there is almost no difference between the two groups or a very weak treatment effect. An effect size is categorized as medium if the interval is less than 0.02 but more than 0.02 to 0.06. There is an effect, but it is not very significant and is considered sufficient. An effect size is stated to have a large or strong effect if the interval reaches 0.6 or more to 0.8. Meanwhile, an effect size that is considered very strong or a strong influence is described by an interval above 0.8 to 1.3.

RESULT AND DISCUSSION

This study aims to determine effect of teaching materials on students' interest in learning and scientific explanation skills. Data were collected through pre-tests, post-tests, and learning interest questionnaires. Before analyzing data to determine differences in learning outcomes, a normality test was conducted. The results of normality test showed that data were normally distributed. Therefore, a paired sample t-test could be used.

Scientific Explanation Results

Based on the results of the Paired Sample t-Test analysis conducted to determine the difference in scores between the pre-test and post-test, the average difference was found to be -14.000 with a standard deviation of 19.029 and a standard error of 4.255.

Tabel 4. Scientific explanation of the results of the paired sample t-test

Paired Samples 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	-14.000	19.029	4.255	-22.906	-5.094	-3.290	19	.004

The negative value of the average difference indicates that the average post-test score is higher than the pre-test score, meaning that there was an increase in scores after the treatment or intervention was administered. The 95% confidence interval for the average difference ranges from -22.906 to -5.094, which is entirely below zero. This indicates that the difference is consistent and statistically significant. The t-test results show a t-value of -3.290 with 19 degrees of freedom (df) and a significance level (Sig. 2-tailed) of 0.004. Since the significance value is less than 0.05 ($p < 0.05$), it can be concluded that there is a significant difference between the pre-test and post-test scores. It can also be concluded that the augmented reality used has a significant effect on students' scientific explanation skills. Subsequently, to prove that augmented reality can influence students' scientific explanation skills, the indicators achieved by students in the Figure 1.

Figure 1. Percentage diagram of scientific explanation indicators

Figure 1 shows the percentage achievement of each scientific explanation indicator, which consists of three main components, namely claim, evidence, and reasoning. Based on the pie chart, the claim indicator has the highest percentage at 37%, followed by reasoning at 32%, and evidence at 31%. The high percentage for the claim indicator indicates that students are relatively capable of presenting statements or answers to scientific phenomena. The ability to state claims is often the easiest initial step because it only requires a direct statement of what is believed to be the correct answer. However, a good scientific explanation does not stop at claims but must be accompanied by supporting evidence and reasoning (Farida et al., 2021). Making a scientific explanation must be reasonable and also have very strong evidence (Chaijalearn et al., 2023). The lower percentages for evidence and reasoning indicators, 31% and 32% respectively, indicate that students still face challenges in linking their claims to relevant data (evidence) and explaining the logical relationship between evidence and claims through reasoning. These indicators are highly influential and interrelated (Niwat Srisawasdi, 2024). To examining the percentage of achievement of scientific explanation indicator, an analysis of learning effectiveness was also conducted by calculating the effect size using Cohen's d formula. This value aims to determine the extent of the influence of the treatment on students' scientific explanation abilities. The following are the results of the effect size.

Table 5. Cohen's d effect size scientific explanation

n	$\bar{X}_1$	$\bar{X}_2$	S_1	S_2	d
20	66	88	16.983	16.859	0.827

The effectiveness of learning on students' scientific explanation skills was analyzed by calculating the effect size using Cohen's d formula. Based on the results shown in Table 3, Cohen's d was 0.827. This value indicates that the treatment or learning intervention had a significant effect on improving scientific explanation skills. According to Cohen's (1988) standard interpretation, an effect size value of 0.827 falls into the large category, meaning there is a significant and practically meaningful improvement.

The average score of students increased from 66 on the pretest to 88 on the posttest, with standard deviations of 16.983 and 16.859, respectively. This increase in scores reflects the development of students' ability to construct scientific explanations that include claims, evidence, and reasoning after participating in the learning process. During the learning process, students were able to express statements that were consistent with the evidence they had obtained. Additionally, students were able to communicate the results of their group discussions. When presented with several problems, students could answer the problems with the help of evidence and also through discussions among students. This indicates that the indicators of evidence and reasoning are progressing positively. The use of AR increases students' active engagement in science learning, which contributes to improved memory and in-depth understanding of concepts, thereby optimally developing scientific explanation skills (Dendodi et al., 2024). Thus, the implemented learning process has proven effective in strengthening students' scientific explanation skills.

Learning Interest Results

To examine the effect of using the Augmented Reality (AR) Assembler on students' learning interest, a paired sample t-test was conducted by comparing students' interest scores before and after the implementation of the AR-based learning intervention. This analysis aimed to identify whether there was a statistically significant difference in students' learning interest as a result of the treatment. The results of the paired sample t-test are presented in Table 6.

Table 6. Results of the Paired Sample t-test on learning interest

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Minat Belajar Awal - Minat Belajar Akhir	-5.050	4.501	1.006	-7.157	-2.943	-5.017	19	.000

The analysis results show an average difference of -5.050 with a standard deviation of 4.501 and a standard error of 1.006. This negative average difference indicates that learning interest after the treatment was higher than before the treatment, as the final score minus the initial score resulted in a negative value. The 95% confidence interval for the score difference ranges from -7.157 to -2.943, which is entirely below zero. This indicates that the observed difference is consistent. Furthermore, the t-value of -5.017 with 19 degrees of freedom (df) resulted in a significance value (Sig. 2-tailed) of 0.000. Since this value is less than 0.05, it can be concluded that the difference between initial and final learning interest is statistically significant. Therefore, it can be concluded that the application of Augmented Reality has an impact on students' learning interest. Furthermore, the presentation on the achievement of learning interest indicators after the application of augmented reality is elaborated upon. The following is a presentation on learning interest indicators.

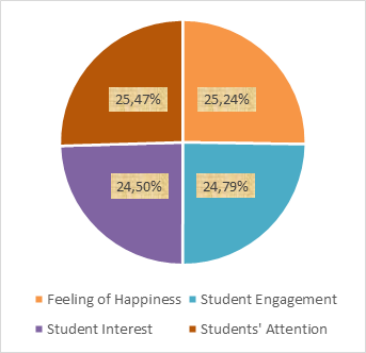

Figure 2. Percentage diagram of learning interest indicators

Based on Figure 2, the results of the analysis of learning interest indicators show that the four indicators measured show a relatively balanced distribution. The student attention indicator had the highest percentage at 25.47%. The student attention indicator includes how students pay attention and listen to the teacher's explanations. There were six statements in the student attention indicator, consisting of three positive statements and three negative statements. According to Syahputra (2020), factors that can influence students' interest in learning include internal factors originating from the students themselves, which include students' attention to learning and their curiosity about lessons, as well as external factors in the form of encouragement from other parties, such as teachers and parents.

The second indicator was happiness, at 25.24%. This indicator included students' expressions of happiness with lessons using media and their enjoyment of completing assigned tasks. There were eight statements in the happiness indicator in this study, consisting of four positive statements and four negative statements. During the learning process, students appeared happy and enthusiastic in exploring the solar system using AR media. Assembler-based AR media succeeded in creating a more enjoyable learning atmosphere, stimulating students' feelings of happiness, which led to high scores for students' interest in learning. This is in line with the research by Putri et al. (2024), which states that the use of augmented reality-based learning media can increase students' interest and feelings of happiness because this media provides an interactive and enjoyable learning experience.

The next indicator, which ranks third, is student engagement at 24.79%. This indicator includes student activity in learning and actively answering and asking questions. The number of statements on the student engagement indicator in this study consists of eight statements, comprising four positive statements and four negative statements. This is in line with research by Sanjaya (2024) that AR media has been proven to be effective in influencing learning interest, students' interaction, and understanding of the material. This indicates that AR media has great potential as an innovative and interesting learning medium. With an immersive learning experience, students become more actively engaged and enjoy the learning process (Lai et al., 2019; Ahmad & Junaini, 2020).

Finally, the last indicator is student interest, which is 24.50%. The number of statements on the student interest indicator in this study consisted of 8 statements, comprising 4 positive statements and 4 negative statements. According to Ossy et al. (2016), AR media that is designed to be attractive with advantages can broaden students' perceptions of an object and provide students with an experience of the 3D object displayed, allowing students to interact in ways that cannot be done in the real world, and can be used with various devices according to availability and needs. AR presents material in a visual, realistic, and interactive way that stimulates curiosity and encourages student attantion (Prijambodo et al., 2024). Thus, AR media can stimulate students' interest in the material being studied.

Based on the almost equal percentages in the four indicators of learning interest, it indicates that all aspects of learning interest have an important contribution in reflecting the emotio-

nal and cognitive involvement of students in the learning process. The high level of attention of students shows that the learning material or method used is able to focus their attention and concentration on learning activities (Cahyaningrum et al., 2024).

Table 7. Cohen's d effect size scientific learning interest

n	$\bar{X}_1$	$\bar{X}_2$	S_1	S_2	d
20	76.75	81.80	3.354	5.644	1.087

Based on Table 4, Cohen's d effect size was 1.087, indicating that the learning intervention had a significant effect on increasing students' interest in learning. According to Cohen's criteria (1988), a d value > 0.8 is categorized as a large effect, so this result shows that the change in learning media applied has a significant impact on improving students' affective aspects, particularly their learning interest.

The average score for student interest in learning increased from 76.75 in the pretest to 81.80 in the posttest, with standard deviations of 3.354 and 5.644, respectively. This increase indicates that the learning designed not only targets cognitive aspects but also facilitates students' emotional involvement in the learning process, such as feelings of joy, attention, interest, and active involvement. Students' emotional involvement is very important for increasing their interest in learning (Astuti et al., 2022). Therefore, it can be concluded that the use of technology, particularly Augmented Reality (AR), has been proven to provide innovative, interactive, flexible learning methods and increase interest in learning (Dhaas, 2024; Rullyana & Triandari, 2024; Alhebaishi & Stone, 2024). This is in line with previous research on the use of audio-visual learning media, which can increase students' interest in learning because audio-visual learning media allows students to see visually, thereby helping them to understand the lesson (Saputra & Nasucha, 2024). Another study conducted by Widyastuti, Mamin, & Tawil (2023) also states that the use of multimedia in learning has advantages in attracting students' interest in learning.

During the lesson, students were very interested in using augmented reality. Students were able to express their opinions about the knowledge they had. During the lesson, students were also able to find evidence in augmented reality with 3D images. Although some students needed help operating augmented reality, they were very enthusiastic about finding information. Fun learning that encourages students to participate actively can also improve their understanding of the lesson. AR contributes positively to academic achievement and student engagement at various levels of education (Arpan et al., 2024; Gusmaneli Gusmaneli et al., 2024).

Based on the results of this study, the application of Augmented Reality (AR) in science teaching has a significant impact on education. First, AR technology provides a creative solution to overcome difficulties in learning abstract concepts in the field of science. With the ability to visualize interactively in three dimensions, AR is able to transform complex material into a real and easy-to-understand learning experience, thereby strengthening students' conceptual understanding. Second, this study proves that the integration of technology not only affects the cognitive aspect, but also the emotional side of students. There was a significant increase in learning interest as seen from indicators of the extent to which students' attention, feelings of happiness, and active involvement indicate that enjoyable and immersive learning experiences can increase student motivation. The learning applied has proven to be effective in creating a fun learning atmosphere and motivating students to be more active and interested in participating in learning. These results reinforce the importance of designing innovative and fun learning to foster a high interest in learning among students.

CONCLUSION

This study proves that the use of Augmented Reality (AR) assisted by Assembler significantly improves the ability of scientific explanation and students' interest in learning science. The analysis showed an increase in the average scientific explanation score from 66 (pre-test) to 88 (post-test), with a large effect (Cohen's d = 0.827). Although the claim indicator achieved the highest percentage (37%), learners still needed reinforcement in linking evidence (31%) and reasoning (32%). On the other hand, interest in learning also increased, indicated by an increase in the mean score from 76.75 to 81.80, with a very large effect (Cohen's d = 1.087). Indicators such as attention, pleasure, and engagement showed a balanced distribution, reflecting learners' enthusiasm. These findings confirm that AR not only facilitates the understanding of abstract science concepts through interactive visualization, but also creates a fun and motivating learning experience. Thus, the integration of AR in science learning is worth considering as an innovative strate-

gy to improve the quality of science education. This research provides a strong foundation for the potential use of AR in science education, but there are still a number of methodological and technological challenges that need to be addressed in future studies. AR is not an instant solution, but rather a tool that must be combined with appropriate teaching strategies. In the future, this study could be applied to a variety of science subjects and used by other science teachers. Furthermore, it could be packaged into a more engaging teaching tool by incorporating more interactive elements.

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