

Development of Environment-Based Augmented Reality Learning Media to Improve Students' Scientific Creativity Abilities

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Abstract

Scientific creativity is an important competency in 21st-century science education. However, many students still show limited ability to generate original and flexible scientific ideas. This study aims to develop an environment-based augmented reality (AR) learning media and to test its validity, practicality, and effectiveness in enhancing students' scientific creativity. A research and development design using the ADDIE model was used. Participants were junior high school students who used the developed Augmented Reality media during science learning. Data were collected through expert validation sheets, observation sheets, scientific creativity tests, and student response questionnaires. The results showed that the media achieved a high level of validity (90%), was very practical to implement (94%), and demonstrated moderate effectiveness in enhancing scientific creativity (N-gain = 0.68). This research contributes to the field by providing a specialized pedagogical framework that bridges abstract environmental concepts with interactive digital visualization, offering a scalable solution to stimulate divergent thinking in science classrooms. Furthermore, this study supports the achievement of Sustainable Development Goals Goal 3 Good Health and Well-being and Goal 4 Quality Education by enhancing students' higher-order thinking skills through innovative technology-based learning. These findings indicate that environment-based Augmented Reality is effective in improving students' scientific creativity and supporting sustainable development.

Keywords: Augmented Reality, Environment-based Learning, Scientific Creativity, Science.

SDGs: Goal 4 (Quality Education), Goal 3 (Good Health and Well-being)

Manuscript History

Received: December 29, 2025

Revised: April 26, 2026

Accepted: May 5, 2026

How to cite:

Tiana, A., Wicaksono, I., Hanafi, H.F., Sutarto, and Indrawati. (2026). Development of Environment-Based Augmented Reality Learning Media to Improve Students' Scientific Creativity Abilities. *International Journal of Research and Community Empowerment*, 4(2), 141-152. DOI: <https://doi.org/10.58706/ijorce.v4n2.p141-152>.

INTRODUCTION

The rapid advancement of digital technology has transformed educational practices and highlighted the importance of 21st-century skills, particularly creativity in science learning. Scientific creativity is considered a crucial competence that enables students to generate original ideas, design scientific investigations, and solve problems innovatively (Aini et al., 2022). Recent studies emphasize that scientific creativity plays a significant role in helping students respond to complex scientific and environmental challenges (Fauzia et al., 2024). Students with higher levels of scientific creativity tend to demonstrate stronger conceptual understanding and improved decision-making skills in science contexts (Wicaksono et al., 2017). Therefore, fostering scientific creativity has become a central objective of contemporary science education.

The importance of scientific creativity is closely related to global educational goals, particularly Sustainable Development Goals (SDGs) 4 (Quality Education) and SDGs 3 (Good Health and Well-being).

Scientific literacy and creativity support students in making informed decisions related to environmental sustainability and health issues (Aninnas et al., 2023). Consequently, science learning should not only emphasize content mastery but also focus on developing students' creative and critical scientific thinking.

Various instructional strategies have been explored to enhance scientific creativity, including inquiry-based learning and problem-based learning. Technology-enhanced learning environments have gained increasing attention due to their potential to support higher-order thinking skills (Prasetya et al., 2024). Digital technologies such as simulations and augmented reality enable students to visualize abstract scientific phenomena and explore multiple solution pathways (Rohmani et al., 2024). Empirical evidence indicates that AR-based learning can improve students' engagement and conceptual understanding in science learning (Ladykova et al., 2024).

Over the past five years, augmented reality has been widely implemented in science education across different educational levels. Several studies report that augmented reality contributes positively to students' learning outcomes and motivation by providing interactive and immersive learning experiences (Ratnasari & Ahmadi, 2025). Systematic reviews further highlight that augmented reality supports the visualization of abstract scientific concepts and enhances student engagement (Mansour et al., 2025). However, most augmented reality studies primarily focus on academic achievement and usability rather than explicitly addressing scientific creativity as a distinct learning construct (Zekeik & Sefian, 2025).

Recent research has begun to explore the relationship between Augmented Reality and higher-order thinking skills, including creativity and critical thinking. These studies suggest that Augmented Reality has the potential to foster creative thinking through interactive exploration and problem-based scenarios (Ferrari et al., 2024). Nevertheless, many of these studies are conducted in higher education settings or assess creativity in a limited manner without using comprehensive scientific creativity indicators (Simon et al., 2025). As a result, empirical evidence at the secondary education level remains limited.

In parallel, environment-based learning has been shown to strengthen contextual understanding and increase students' awareness of real-world environmental issues. Learning activities that integrate environmental contexts encourage students to connect scientific concepts with everyday phenomena and sustainability challenges (Komalasari & Septiani, 2023). Environment-based approaches also contribute to the development of students' scientific reasoning and creativity (Saputra et al., 2024). However, most studies in this field do not integrate immersive digital technologies to support creative scientific idea generation (Jannah et al., 2023).

Recent studies indicate that combining real-world environmental contexts with interactive augmented reality visualizations can more effectively promote scientific imagination and creative experimentation. Contextualized augmented reality learning allows students to explore environmental phenomena through multiple scientific perspectives (Peikos & Sofianidis, 2024). Empirical findings also suggest that such integration enhances students' divergent thinking and problem sensitivity (Alali & Wardat, 2025). Despite these promising findings, research that systematically integrates environment-based learning with augmented reality remains limited.

Existing augmented reality research tends to prioritize technological features and usability rather than explicitly linking environmental issues with structured scientific creativity indicators. Indicators such as unusual uses, scientific imagination, problem sensitivity, creative problem solving, and product design are rarely addressed comprehensively (Syskowski & Wilfinger, 2024). Recent studies also highlight the need for augmented reality learning designs that go beyond visualization and explicitly target creative scientific outcomes (Kazlaris & Keramopoulos, 2025). Consequently, the potential synergy between environment-based learning and augmented reality has not been fully explored.

Therefore, a clear research gap exists in the development and empirical evaluation of environment-based augmented reality learning media that systematically targets the enhancement of students' scientific creativity at the junior high school level. Few studies have examined such media comprehensively in terms of validity, practicality, and effectiveness. This study aims to develop environment-based augmented reality learning media and to evaluate its validity, practicality, and effectiveness in improving students' scientific creativity. The findings are expected to contribute to the advancement of technology-integrated science education and support the achievement of SDGs 4 (Quality Education) and SDGs 3 (Good Health and Well-being).

METHOD

This study employed a Research and Development (R&D) approach aimed at developing and evaluating the effectiveness of an instructional product. The development design followed the ADDIE model, which consists of five stages: Analyze, Design, Development, Implementation, and Evaluation (Branch, 2009). The research object was an environment-based augmented reality learning medium developed using the Assemblr Edu application. The participants were 32 seventh-grade junior high school students who were involved during the implementation stage, while three experts served as validators and three observers were involved in practicality assessment.

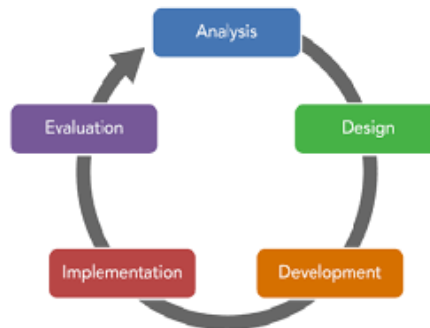


Figure 1. ADDIE Model Development Procedures

The image shows the ADDIE model, which includes Analysis, Design, Development, Implementation, and Evaluation. It is a continuous cycle used to design and improve learning processes, where each stage has a specific role, such as identifying needs, creating materials, applying them, and evaluating the results for improvement. During the analysis stage, interviews with science teachers were conducted to identify learning needs and challenges related to scientific creativity and technology integration. The design stage involved planning the structure of the augmented reality learning media, including environmental content integration, augmented reality visualization elements, learning flow, and the development of research instruments such as validation sheets, observation sheets, scientific creativity tests, and student response questionnaires. In the development stage, the AR media prototype was produced and validated by experts, and revisions were made based on their feedback. The implementation stage involved trying out the revised augmented reality media in classroom learning activities, during which data on practicality, effectiveness, and student responses were collected. Finally, the evaluation stage included formative evaluation throughout the development process and summative evaluation after implementation to determine overall media quality.

Data were collected using interviews, questionnaires, observations, and scientific creativity tests. Interviews to identify instructional needs, followed by expert validation sheets to assess the media's feasibility based on content, media and visual presentation, usability, and language. The practicality of the media was evaluated through observation sheets during classroom implementation, while its effectiveness was measured using a scientific creativity test (pre-test and post-test) encompassing seven key indicators: unusual uses, scientific imagination, sensitivity to science problems, creative science problem solving, creative experiment, technical product improvement, and creative science product design. Additionally, student response questionnaires were used to capture students' perceptions of media use.

Data analysis focused on evaluating the validity, practicality, and effectiveness of the developed augmented reality learning media. Media validity was calculated using Equation (1).

$$V_{ah} = \frac{Tse}{Tsh} \times 100 \quad (1)$$

where V represents the validity score, Tse is the total empirical score obtained from validators, and Tsm is the maximum possible score. The validity scores were interpreted based on the criteria presented in Table 1, which categorize the media validity level.

Table 1. Validity Analysis Criteria

| Criteria | Validity Level |
|-----------------------|----------------|
| $80\% \leq X < 100\%$ | Highly Valid |
| $60\% \leq X < 80\%$ | Valid |
| $40\% \leq X < 60\%$ | Valid |
| $20\% \leq X < 40\%$ | Not Valid |
| $0\% \leq X < 20\%$ | Higly invalid |

According to Table 1 the criteria for interpreting validity analysis results based on percentage scores. Scores of 80–100% indicate high validity, meaning the product is ready for use without revision, while scores of 60–80% are categorized as valid with minor improvements needed. Scores between 40–60% suggest the product is valid but requires revision, whereas 20–40% indicates not valid and needs major revision. Scores below 20% reflect high invalidity, showing that the product is not feasible for use (Rahmasari et al., 2025).

Media practicality was analyzed using observation data collected during implementation. The practicality score was calculated using Equation (2).

$$\text{Practicality score (\%)} = \frac{\text{Score Obtained}}{\text{Maximum Score}} \times 100\% \quad (2)$$

The resulting percentages were interpreted according to the practicality criteria shown in Table 2, which classify the media as very practical, practical, less practical, or not practical.

Table 2. Practicality Criteria

| Criteria | Category |
|--------------|----------------|
| > 75% - 100% | Very Practical |
| > 50% - 75% | Practical |
| >25% - 50% | Less Practical |
| 0% - 25% | Not Practical |

According to Table 2 the criteria used to determine the practicality level of the learning media based on percentage scores. Scores above 75% indicate the media is very practical and easy to implement, while scores between 50% and 75% fall into the practical category. Scores ranging from 25% to 50% are classified as less practical, suggesting notable revisions are needed, whereas scores below 25% indicate the media is not practical for use in learning activities (Irsyadunas et al., 2021).

Media effectiveness was evaluated through improvements in scientific creativity test scores and student response data. The improvement in scientific creativity was analyzed using the normalized gain (N-gain) formula presented in Equation (3).

$$N\text{-gain} = \frac{\text{Score posttest} - \text{score pretest}}{\text{Score Maximum} - \text{Score pretest}} \quad (3)$$

The N-gain values were interpreted based on effectiveness criteria presented in Table 3, classifying effectiveness levels as high, moderate, or low.

Table 3. N-gain Assessment Criteria

| N-gain Score | Category |
|--------------------------------|----------|
| $N\text{-gain} \geq 0.7$ | High |
| $0.7 > N\text{-gain} \geq 0.3$ | Moderate |
| $N\text{-gain} < 0.3$ | Low |

According to Table 3 describes the N-gain assessment criteria used to evaluate the improvement in students' learning outcomes. An N-gain score greater than 0.7 indicates a high level of improvement, reflecting substantial learning gains. Scores between 0.3 and 0.7 are categorized as moderate, showing a meaningful but not optimal increase, while N-gain values below 0.3 are classified as low, indicating limited improvement after the learning intervention (Setvia et al., 2022).

In addition, student response data were analyzed using Equation (4).

$$P = \frac{F}{N} \times 100\% \quad (4)$$

where P is the percentage of student responses, F is the total average score obtained, and N is the maximum possible score. The student response percentages were categorized based on criteria presented shows in Table 4.

Table 4. Analysis of Student Response Criteria (Rizkika et al., 2022)

| Percentage | Category |
|---------------------------|-----------|
| $81.25\% < P \leq 100\%$ | Very Good |
| $62.5\% < P \leq 81.25\%$ | Good |
| $43.75\% < P \leq 62.5\%$ | Less Good |
| $25\% < P \leq 43.75\%$ | Not Good |

According to Table 4 the criteria for analyzing student responses to the learning media based on percentage scores. Student responses with percentages between 81.25% and 100% are categorized as very good, indicating a highly positive perception of the media. Percentages ranging from 62.5% to 81.25% fall into the good category, reflecting favorable responses, while scores between 43.75% and 62.5% are classified as less good, showing moderate acceptance. Percentages from 25% to 43.75% are considered not good, indicating low student responses to the learning media.

RESULTS AND DISCUSSION

This study was conducted through a series of development stages to create an augmented reality learning medium based on the environment that aims to improve students' scientific creativity. The developed media was then implemented on seventh-grade students at State Junior High School 3 Tanjunganom. The development process went through stages of validity, practicality, and effectiveness to ensure that the resulting media was of good quality, easy to apply in the learning process, and could make a significant contribution to students' scientific creativity. The entire development process was carried out using the ADDIE model below.

The analysis stage was carried out through interviews with science teachers and observations at State Junior High School 3 Tanjunganom. The results showed that the school had implemented the Merdeka Curriculum, which provides freedom in learning and encourages student activity. However, the learning process was still dominated by the use of worksheets and textbooks due to the limited availability of technology-based media. This resulted in learning activities that were more textual in nature, less interactive, and some students had difficulty understanding the material in depth and relating it to their daily lives. In addition, the observation results showed that the students' level of concern for the environment was relatively low, as seen from their habit of littering even though supporting facilities had been provided.

The planning stage focused on designing learning tools and research instruments, including the preparation of learning objective flow, teaching modules, a guidebook for environment-based augmented reality media, and pre-test and post-test questions to assess the improvement in students' scientific creativity. This stage also establishes the outline and basic concept for developing media that links material and its changes to real environmental issues through the use of environment-based augmented reality technology as a learning visualization tool.

The process of designing the environment-based augmented reality media involved collecting and organizing instructional materials to support contextual science learning. The collected materials included learning content, images, three-dimensional illustrations, and storyboards that guided the sequence of media presentation. The media were developed using the Assemblr Edu application by designing the interface, navigation structure, and the integration of visual and textual elements in a systematic manner. The environment-based augmented reality media were structured into three scenes in each subchapter to support the development of students' scientific creativity. Figure 2 shows the presentation of environmental issues, Figure 3 shows the core material display, and Figure 4 shows the scientific creativity exercise display.

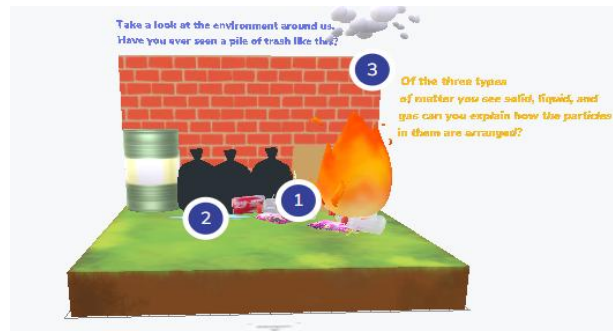


Figure 2. Presentation of Environmental Issues

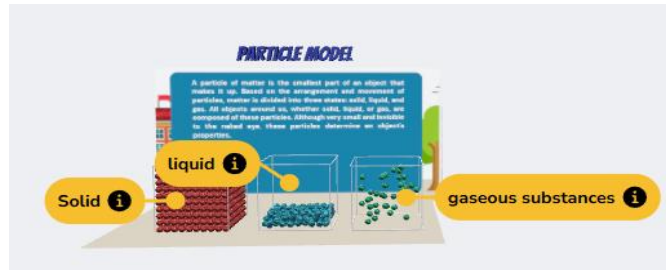


Figure 3. Core Material Display

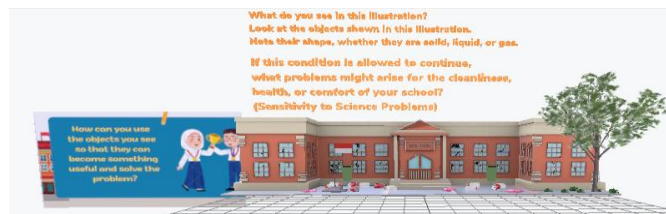


Figure 4. Scientific Creativity Exercise Display

According to Figure 1, environmental issues were presented at the beginning of each subchapter to stimulate students’ awareness of real-world problems. Figure 2 illustrates the core material display, which provided explanations of scientific concepts through interactive three-dimensional visualizations to support conceptual understanding. Figure 3 demonstrates the scientific creativity exercise display, which encouraged students to generate ideas, analyze problems, and propose creative solutions based on environmental contexts. The integration of these three scenes allowed students to connect scientific concepts with everyday environmental phenomena. This design supported meaningful learning and fostered the development of scientific creativity.

The development stage of the previously designed environmental-based augmented reality media prototype. After that, the prototype was validated by three validators to assess its feasibility before the was tested on students. Table 5 shows the results of the validation analysis of the environment-based augmented reality media.

Table 5. Results of the validation of the environment-based augmented reality media

| Aspect | Average (%) | Average Validity (%) | Validity Level |
|-----------------------------|-------------|----------------------|----------------|
| Material | 90% | 90% | Highly Valid |
| Media and presentation | 92% | | |
| Ease of use | 88% | | |
| Material Media and Language | 91% | | |

According to Table 5, the validation results show that the environment-based augmented reality media obtained an average score of 90%, which is classified as highly valid. This finding indicates that the developed media met feasibility standards and was suitable for use in learning activities without requiring major revisions. This result is consistent with the study by Muafa and Anggaryani (2024), which reported an average validity score of 93% for augmented reality learning media. High validity scores indicate that augmented reality media can effectively support instructional objectives when appropriately designed.

The material aspect achieved a score of 90%, indicating that the content aligned well with learning objectives and supported students' conceptual understanding. This finding supports the statement by Hariyanti et al. (2021) that learning media facilitate faster comprehension of learning materials. The media and presentation aspect obtained the highest score of 92%, showing that the visual design, three-dimensional elements, and interactivity were effective in enhancing student engagement. Previous research has shown that the integration of text, images, and audio in augmented reality media increases learning interest and effectiveness (Benu et al., 2022).

The ease-of-use aspect scored 88%, indicating that the media could be operated easily, although minor improvements to usage instructions were still needed. The flexibility and accessibility of augmented reality media allow students to learn independently anytime and anywhere, making it a promising educational innovation (Maziyah & Zumrotun, 2025). The language aspect achieved a score of 91%, classified as highly valid, indicating that the language used was communicative and appropriate for junior high school students. Clear and effective language use is essential to ensure accurate message delivery in learning media (Wahyu et al., 2021).

The implementation stage was carried out after the augmented reality-based learning media was declared valid. Next, the media was tested on 32 seventh-grade students at state junior high school 3 Tanjunganom to assess the practicality of the media in learning. During this stage, observers used observation sheets to assess the implementation of media use, student involvement, and media support for increasing students' scientific creativity. Table 6 shows the results of the analysis of the practicality of the environment-based augmented reality media.

Table 6. Results of the Analysis of the Practicality of the Environment-Based Augmented Reality Media

| Activity | Meeting Practically (%) | | | | Average (%) | Category |
|---|-------------------------|-----------|-----------|-----------|-------------|-----------------------|
| | 1 | 2 | 3 | 4 | | |
| The implementation of environment-based augmented reality media | 83 | 91 | 92 | 94 | 90 | Very practical |
| Student involvement | 95 | 93 | 95 | 97 | 95 | Very practical |
| Implementation of scientific creativity indicators | 100 | 100 | 92 | 96 | 97 | Very practical |
| Average | 93 | 95 | 93 | 96 | 94 | Very practical |

According to Table 6, the practicality of the media obtained an average score of 94% with a criterion of very practical, which means that this environment-based augmented reality media can be used easily. In terms of media feasibility, it scored 90%, indicating that students could use the media well, from installing the application, scanning markers, to using three-dimensional objects efficiently without any significant difficulties, in line with the findings of Zulham & Budihartanti, (2016), which stated that augmented reality media is very easy to use in Android-based learning. In terms of student engagement, the average score was 95%, indicating that the media can increase enthusiasm, active participation, and cooperation among students in the learning process, in line with the results of the study Rachim et al. (2024) that augmented reality media can increase student participation and engagement in learning. Meanwhile, in terms of implementation, the scientific creativity indicator scored 97%, which shows that this media can practically improve students' scientific creativity, as stated by Hafizah et al. (2025) who stated that augmented reality media is easy to use, interesting, and supports students' understanding and creativity.

The evaluation stage was conducted to assess the effectiveness of the environment-based augmented reality media. Effectiveness was assessed through pre-test and post-test questions to identify improvements in students' scientific creativity. Furthermore, the pre-test and post-test results were analyzed using N-gain to determine the level of effectiveness of the media in improving students' scientific creativity. Table 7 shows the results of the analysis of the effectiveness of the environment-based augmented reality media.

Table 7. Results Analysis

| Data | Grade VII-2 | |
|--------------------|-------------|-----------|
| | Pre-test | Post-test |
| Number of students | 32 | |
| Lowest score | 30 | 62.5 |
| Highest score | 70 | 100 |
| Average | 52.57 | 84.37 |
| N-Gain | 0.68 | |
| Category | Moderate | |

According to Table 7, the evaluation stage was carried out to measure the effectiveness and make improvements to the environment-based augmented reality learning media product. Effectiveness was measured through pre-tests and post-tests to determine the increase in students' scientific creativity before and after using the media, as well as through student response questionnaires to obtain an overview of their responses after participating in learning with environment-based augmented reality media. The analysis results indicate that the effectiveness of the environment-based augmented reality learning media produced an N-gain value of 0.68, which falls within the moderate criteria. This indicates that this media is quite effective in increasing students' scientific creativity. These results are in line with the study by Chabibah et al. (2024), which recorded an N-gain value of 0.6830, and research by Bata & Sangi (2023), which obtained an N-gain of 0.5421, also falling into the moderate category.

To obtain a more detailed description of the improvement in students' scientific creativity, an N-gain analysis was conducted for each scientific creativity indicator. This analysis aimed to identify the extent to which each indicator developed after the implementation of the environment-based augmented reality learning media. The N-gain values provide information on the level of improvement achieved in each indicator, categorized into low, moderate, or high levels. Furthermore, the analysis highlights which aspects of scientific creativity were most strongly supported by the learning media. Table 8 shows the N-gain results for each scientific creativity indicator.

Table 8. N-gain Results for Each Scientific Creativity Indicator

| Indicator | Average Score | | N-Gain | Category |
|----------------------------------|---------------|----------|--------|----------|
| | Pretest | Posttest | | |
| Unusual uses | 48.43 | 79.68 | 0.61 | Moderate |
| Scientific imagination | 41.40 | 80.46 | 0.67 | Moderate |
| Sensitivity to science problems | 58.59 | 85.54 | 0.65 | Moderate |
| Creative science problem solving | 49.20 | 88.28 | 0.77 | High |
| Creative experiment | 50 | 86.71 | 0.73 | High |
| A technical product improvement | 52.77 | 82.81 | 0.63 | Moderate |
| Creative science product design | 64.84 | 84.37 | 0.56 | Moderate |

According to Table 8, the N-gain analysis indicates that the environment-based augmented reality learning media improved students' scientific creativity at moderate to high levels across all indicators. Most indicators showed moderate improvement, while creative science problem solving and creative experiments reached high improvement categories. These findings suggest that the integration of augmented reality with environmental contexts effectively supported the development of students' scientific creativity. Differences in improvement levels reflect variations in the cognitive and creative demands of each indicator.

Several indicators, including unusual uses, scientific imagination, sensitivity to scientific problems, technical product improvement, and creative science product design, showed moderate improvement after the implementation of the learning media. The improvement in unusual uses indicates that students were able to generate alternative ideas based on environmental contexts, which is an essential component of creative thinking as described by Inayah (2020). The development of scientific imagination suggests that students became more capable of visualizing scientific processes, supporting the view of Aini et al. (2022) that imagination enhances creative learning. Increased sensitivity to scientific problems reflects students' ability to recognize relevant environmental issues, as emphasized by Palah et al. (2017). The improvement in technical product and product design indicators aligns with the findings of Setyadin et al. (2019) and Yulia et al. (2024), who highlighted the role of scientific understanding in developing creative and functional products.

Creative science problem solving and creative experiments demonstrated the highest levels of improvement among the scientific creativity indicators. This result indicates that the environment-based augmented reality media effectively supported students in analyzing environmental problems and generating creative solutions. The improvement in creative problem solving is consistent with the findings of Zulaichah et al. (2021), who reported that creative problem-solving activities enhance students' ability to design scientific solutions. Similarly, the increase in creative experimental skills supports the findings of Yulia et al. (2024), which emphasize the importance of experimental creativity in deepening students' scientific insight.

The effectiveness of environment-based augmented reality learning media was also measured through a student response questionnaire filled out by 32 students after participating in learning using environment based augmented reality media. The collected data was then analyzed to determine student responses regarding their experience using environment-based augmented reality learning media. Table 9 shows the results of the student response questionnaire analysis.

Table 9. Results of the Student Response Questionnaire Analysis

| Total Aspect | Average Score | Percentage | Criteria |
|--------------|---------------|------------|-----------|
| 17 | 3.58 | 89.48% | Very Good |

According to Table 9, data from the questionnaire given to students shows significant support for the effectiveness of using environment-based augmented reality learning media. The average score obtained was 3.58 with a percentage of 89.48% which is classified as very good. These results show that this media is considered interesting, easy to use, and helps students understand the material better. This finding is in line with the research Seviana et al. (2022) which reports that student responses reached a score of 86.66, which is in the excellent category. This finding is also reinforced by the research Uno (2024) which reveals that the use of augmented reality media can encourage student motivation in science learning. In addition to increasing motivation, the use of this media makes the learning process more active and enjoyable for students, relevant to the context of the students' environment, and encourages active student involvement during discussions and exploration of science concepts.

This study has several limitations that should be considered when interpreting the findings. The implementation of the environment-based augmented reality learning media was limited to a single class, which restricts the generalizability of the results to broader student populations. In addition, the learning material focused on one science topic, and the evaluation of scientific creativity was conducted within a relatively short intervention period. Future studies are recommended to involve larger and more diverse samples, apply the media to various science topics, and integrate more advanced AR features to further optimize the development of students' scientific creativity.

The findings of this study indicate that environment-based augmented reality learning media has the potential to contribute to the achievement of Sustainable Development Goals, particularly SDG 4 (Quality Education) and SDG 3 (Good Health and Well-being). By fostering students' scientific creativity through contextual environmental issues, the media supports meaningful science learning and enhances students' ability to make informed decisions related to health and environmental sustainability. Furthermore, the integration of digital technology in science learning promotes innovative and inclusive educational practices, which are essential for preparing students to address complex environmental and health challenges in a sustainable future.

CONCLUSION

Environment-based augmented reality offers an innovative approach by connecting scientific concepts with real environmental contexts through engaging visual and interactive representations. Overall, this study concludes that environment-based augmented reality learning media has strong potential to support science learning by fostering students' scientific creativity and strengthening the integration of digital technology in classroom practices. The combination of contextual environmental content and interactive visualization promotes meaningful engagement and facilitates creative scientific thinking. However, this study is limited by the relatively small number of participants and the focus on a single science topic. Therefore, future research may further develop this learning media by implementing it on a larger scale, applying it to diverse science materials, and integrating more advanced technological features to maximize its impact on students' scientific creativity.

AUTHOR CONTRIBUTIONS

Ainun Tiana: Conceptualization, Methodology, Software, Formal Analysis, Investigation, Resources, Data Curation, and Writing - Original Draft; **Iwan Wicaksono:** Writing - Review & Editing and Project Administration; **Hafizul Fahry Hanafi:** Validation, Visualization, and Supervision; **Sutarto:** Data Curation and Validation; and **Indrawati:** Writing - Review & Editing and Funding Acquisition. All authors have read and approved the final version of this manuscript.

DATA AVAILABILITY STATEMENT

The data supporting the findings of this study are available from the authors upon reasonable request, subject to ethical approval and institutional regulations.

DECLARATION OF COMPETING INTEREST

The authors declare no known financial conflicts of interest or personal relationships that could have influenced the work reported in this manuscript.

DECLARATION OF ETHICS

The authors declare that the research and writing of this manuscript adhere to ethical standards of research and publication, in accordance with scientific principles, and are free from plagiarism.

DECLARATION OF ASSISTIVE TECHNOLOGIES IN THE WRITING PROCESS

The authors declare that generative artificial intelligence (Gen AI) and other AI-assisted tools were used prudently, not excessively, during the research and preparation of this manuscript. Specifically, ChatGPT was used for brainstorming ideas; QuillBot was used for paraphrasing, and Perplexity was used for synthesizing evidence from the literature. All AI-generated material was reviewed and edited for accuracy, completeness, and compliance with ethical and scholarly standards. The authors accept full responsibility for the final content of the manuscript.

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