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THE EFFECTIVENESS OF INTERACTIVE MULTIMEDIA BASED ON AUGMENTED REALITY IN GEOGRAPHY LESSONS TO IMPROVE LEARNING OUTCOMES

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ABSTRACT

This study aimed to examine whether interactive multimedia based on Augmented Reality (AR) can improve students' learning outcomes in the Natural Disaster Mitigation topic at MA Ahmad Yani Jabung. The research employed a quantitative approach with a one-group pretest–posttest design involving 16 Grade XI students selected through purposive sampling. A 12-item multiple-choice test was used to measure learning outcomes and was validated through expert judgment, Pearson's correlation, and reliability testing, yielding Cronbach's Alpha coefficients of 0.874 (pretest) and 0.904 (posttest). Data were analyzed using a paired t-test and N-Gain score. The results revealed a notable improvement, with average scores increasing from 55.21 (pretest) to 82.81 (posttest), categorized as moderate to high improvement based on the N-Gain value. The paired t-test indicated a statistically significant difference in students' scores before and after the intervention ($p < 0.05$). These findings demonstrate that AR-based interactive multimedia is effective in enhancing geography learning outcomes by providing engaging, interactive, and contextually meaningful learning experiences.

INTRODUCTION

The rapid advancement of digital technologies has significantly transformed educational practices. Teachers must adjust to the use of technology that can enhance the efficacy of the learning process as learning systems transition into the digital age. The 21st century's dynamics require critical thinking, teamwork, and innovation, and digital literacy as key competencies that must be developed in students. The application of technology in education goes

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beyond its role as a mere tool; rather, it serves as a means to create an active, collaborative, and experience-based learning environment (Haleem et al., 2022; Sabri et al., 2024). The use of innovative learning media is an urgent need so that the learning process is no longer just a transfer of information, but also the formation of meaning through meaningful learning experiences.

A major challenge in geography instruction stems from its inherently abstract and highly visual content, which requires visualization and interpretation skills to understand spatial and geosphere phenomena. Subjects such as lithosphere dynamics, the atmosphere, natural disaster mitigation, and human interaction with the environment are often abstract, requiring adequate visual representation. Geography learning will be more effective if the media used can help students understand spatial relationships and processes occurring on the earth's surface in concrete terms (Favier & Schee, 2014; Krüger et al., 2022). However, in reality, learning in schools is still dominated by a verbalistic approach that relies on textbooks and lectures. This condition makes it difficult for students to build deep conceptual representations, so that learning outcomes do not reach an optimal level.

The gap between the visual characteristics of geography material and static learning media is one of the causes of low student motivation and understanding. Non-interactive learning media cause the learning process to become monotonous, reducing student attention and inhibiting cognitive engagement (Rasch & Schnotz, 2009). This reality is reinforced by the demands of the Merdeka Curriculum, which emphasizes active, contextual, and project-based learning that encourages students to explore and discover knowledge independently (Aulya et al., 2025; Namkatu et al., 2025). Therefore, educators are required to provide learning media that can bridge this gap through interactive and visually strong approaches.

Efforts to improve students' learning outcomes can be strengthened by integrating interactive multimedia technologies. ognitive Theory of Multimedia Learning, the learning process becomes more effective when information is presented through a combination of text, images, audio, and animation, because it allows simultaneous processing of visual and verbal information in working memory Mayer, (2005). Interactive multimedia provides a multisensory learning experience that can strengthen students' retention and understanding of concepts. With the development of digital technology, one multimedia innovation that offers the richest learning experience is Augmented Reality (AR), as it is able to interactively combine the real world and virtual objects.

The use of Augmented Reality as a learning medium is a potential solution in overcoming the limitations of visualizing abstract geographical concepts. AR allows students to interact directly with three-dimensional models, thereby transforming passive learning experiences into active and exploratory ones (Mansour et al., 2025; Radu et al., 2023). This technology can be integrated into interactive multimedia such as digital flipbooks that contain text, videos, quizzes, and AR elements. This combination provides space for students to build knowledge through direct exploration of geographical phenomena, in line with the principles of Social Constructivism (Vygotsky, 1969) which emphasizes learning through interaction and real experiences. Various studies consistently demonstrate the effectiveness of AR-based learning, as evidenced by its ability to improve students' understanding of geospheric phenomena, enhance learning outcomes and student activity in Cartography courses, and increase student interest and achievement through interactive three-dimensional visualization (Ernawati & Maulidna, 2023; Fauziah et al., 2025; Sudrajat et al., 2023). However, previous studies predominantly focused on AR for general conceptual mastery, with limited research specifically examining its effectiveness in supporting Natural Disaster Mitigation learning at the senior high school level.

Observations at MA Ahmad Yani Jabung show that the implementation of technology-based learning media is still very limited. Based on the observations, geography lessons still use textbooks and simple PowerPoint presentations as the main resources. Students tend to be passive during the learning process, with low involvement and high dependence on the teacher's explanations. A total of 16 students observed showed minimal participation in class discussions, and the pretest results showed scores below the Minimum Completion Criteria (KKM). This condition confirms problems in the effectiveness of learning and the weak appeal of the media used. Interactive AR-

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based flipbook media containing readings, videos, quizzes, and three-dimensional features is expected to be an innovation that can stimulate student learning engagement while improving their learning outcomes.

The application of interactive multimedia based on Augmented Reality in geography learning is a strategic step to overcome learning problems that have been conventional and do not actively involve students. The integration of this technology provides opportunities for students to understand the concept of natural disaster mitigation through a more realistic and contextual learning experience. Learning is no longer limited to static text and images, but has evolved into an exploratory process that fosters curiosity, critical thinking skills, and students' spatial analysis abilities. In addition to its potential to improve learning outcomes. Additionally, it is anticipated that the use of AR-based media would improve digital literacy and form flexible perspectives on advancements in educational technology. Therefore, it is anticipated that this research will significantly aid in the creation of cutting-edge geography learning models that are relevant to contemporary demands and focused on mastering 21st-century skills. Based on these conditions, this study aims to develop and evaluate the effectiveness of an interactive AR-based flipbook in improving student engagement and learning outcomes in the Natural Disaster Mitigation material at the senior high school level.

METHOD

This study employed a quasi-experimental design and a quantitative methodology. The research subjects received therapy in the form of learning through interactive multimedia based on Augmented Reality (AR) using a One Group Pretest-Posttest Design. Students were given assessments to gauge their learning outcomes both before and after the therapy. This design enabled researchers to evaluate changes in learning outcomes resulting from the intervention before and after the use of media. (Sugiyono, 2019). The research design can be described as follows:

Tabel 1. Research Design

Kelompok	Pretest	Perlakuan	Posttest
Eksperimen	O_1	X	O_2

Description:
O_1 = pretest before treatment
X = treatment with Augmented Reality based interactive multimedia
O_2 = posttest after treatment

Because the researcher was unable to separate the control groups at random due to field conditions, this design was used. Thus, using the same group, the researcher compared the pretest and posttest results to confirm the treatment's efficacy.

The research was conducted at MA of Ahmad Yani, Jabung, Regency of Malang, East Java, Malang Regency, East Java. The site was purposively selected due to the absence of AR-integrated learning media in its instructional practices. The study lasted for two months, starting in September and ending in October 2025, covering phases such as planning, intervention implementation, information gathering, and analysis of findings. The research subjects were 11th grade students at MA Ahmad Yani Jabung in the 2025/2026 academic year. There were 16 students in the class, consisting of 1 male student and 15 female students. The sampling technique used was purposive sampling, considering that the class had homogeneous characteristics in terms of academic ability and had never had any experience of learning using Augmented Reality-based media.

The main tool in this study was a learning assessment, consisting of 15 multiple choice questions compiled in accordance with the basic competency indicators of the Merdeka Curriculum. This tool was used for both the pretest and posttest. Thirty students who were not part of the primary study group were used to validate the instrument for accuracy and consistency. Using Pearson's product-moment correlation, accuracy was assessed using a standard where the calculated r value was higher than the table r value (0.361). The Cronbach's Alpha technique was used to ensure

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uniformity in the evaluation. According to the test findings, both the pretest and posttest instruments proved to be trustworthy and appropriate for use, with alpha values of 0.713 and 0.875, respectively.

The data in this study were obtained through two main stages, namely through learning achievement tests conducted twice, before (pretest) and after (posttest) the implementation of Augmented Reality-based interactive multimedia. These tests aimed to measure the improvement in students' cognitive abilities. Then, Observation of learning activities is used to reinforce quantitative data by documenting student behavior during educational sessions, particularly in relation to their level of engagement and reaction to the learning media used.

Descriptive and inferential statistical techniques were used to evaluate the learning outcomes data. The mean score, mastery percentage, and learning outcome improvement from the pre-test to the post-test were first determined using descriptive analysis. Second, to find significant differences in learning outcomes before and after the use of AR-based interactive multimedia, inferential analysis was carried out using a paired t-test. The Kolmogorov Smirnov test was used to determine the normality of the data before the t-test was performed. Additionally, the N-Gain Score was used to calculate the improvement in learning outcomes using the method from Hake, (1998):

$$N - Gain = \frac{(Posttest - Pretest)}{(100 - Pretest)}$$

The criteria for interpreting N-Gain are:

1. $G < 0.30$ = low improvement
2. $0.30 \leq G < 0.70$ = moderate improvement
3. $G \geq 0.70$ = high improvement

This method provided a comprehensive overview of the effectiveness of AR-based interactive multimedia based on augmented reality may enhance student learning results.

RESULT AND DISCUSSION

Result

This study was carried out at MA Ahmad Yani Jabung to ascertain if employing augmented reality-based interactive multimedia can enhance geography learning results. Preliminary investigations, the creation of research tools, validity and reliability testing, and the administration of pretest and postest were the first steps in the phased research activities. The validity and reliability of the learning outcome test instruments were examined prior to their use in the primary research. The tool assessed students' comprehension of the idea of mitigating natural disasters and consisted of fifteen-choice questions. Using Pearson's Product Moment correlation and SPSS version 26, the validity test was performed on thirty grade XI students who were not in the experimental group.

The r table value of 0.361 with N = 30 at a significance level of 5% was used to establish the validity requirements. If the calculated r exceeded the table r and the significance value (Sig. 2-tailed) was less than 0.05, the questions were deemed valid. Table 1 below displays the results of the validity test.

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Table 2. Pre-test Validity Test Results

No	r hitung	Sig. (2-tailed)	Description
1	0,599	0,000	Valid
2	0,406	0,026	Valid
3	0,511	0,004	Valid
4	0,595	0,001	Valid
5	-0,301	0,105	Invalid
6	0,686	0,000	Valid
7	0,686	0,000	Valid
8	-0,154	0,417	Invalid
9	0,747	0,000	Valid
10	0,740	0,000	Valid
11	-0,450	0,013	Invalid
12	0,593	0,001	Valid
13	0,697	0,000	Valid
14	0,593	0,001	Valid
15	0,697	0,000	Valid

Twelve of the fifteen items that were produced were deemed to be valid based on the findings of the validity test, three items did not fulfill the requirements because their correlation values were either below the minimum limit or showed a negative correlation with the overall score. After then, the three objects were thrown away and never used in the instrument again. Since they were judged to be consistent with the learning markers being assessed, the remaining valid items were kept as the primary instrument. Using the Cronbach's Alpha formula and the SPSS version 26 software, the reliability test was carried out. If an instrument's alpha coefficient value is greater than or equal to 0.6, it is deemed dependent since it shows that its items measure the same construct with sufficient consistency. (Taber, 2018).

Table 3. Pre-test Reliability Test Results

Cronbach's Alpha	N of Items
0,874	12

With a total of 12 items, Table 2 data shows a Cronbach's Alpha value of 0,874. The instrument may be classified as dependent and having strong internal consistency because this value is higher than the minimum limit of 0,6. This demonstrates that each item can reliably evaluate learning outcomes and is suitable for use in future studies.

Following the creation of the pretest, a posttest tool was created to gauge the learning results of students following the use of interactive multimedia based on augmented reality. There were 15 multiple-choice questions on the posttest, which was the same number of items and indications as the pretest. To make sure each question could evaluate cognitive capacity in line with the learning indicators, a validity test was carried out. With the use of the SPSS version 26 software, the Pearson Product Moment correlation approach was used to perform the validity test. If the estimated r value was higher than the table r 0,361 and the significance value (Sig. 2-tailed) was less than 0,05, the item was deemed genuine. Table 3 below displays the findings of the posttest instrument's validity test.

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Table 4. Posttest-test Validity Test Results

No. Soal	r hitung	Sig. (2-tailed)	Keterangan
1	0,657	0,000	Valid
2	0,705	0,000	Valid
3	0,795	0,000	Valid
4	0,709	0,000	Valid
5	0,642	0,000	Valid
6	0,368	0,045	Valid
7	-0,087	0,648	Invalid
8	0,657	0,000	Valid
9	0,705	0,000	Valid
10	0,795	0,000	Valid
11	0,450	0,013	Valid
12	0,538	0,002	Valid
13	0,858	0,000	Valid
14	0,538	0,002	Valid
15	0,858	0,000	Valid

According to Table 3's results, 14 of the 15 items that were evaluated were deemed valid since their calculated r-value was higher than the table r-value and their significant value was less than 0,05. One item, number 7, had a significance value > 0,05 and a negative correlation, making it invalid. The correlation calculation indicates that the selection of items took into account both the appropriateness of the learning markers and statistical validity. Items 5, 7, and 11 were determined to be eliminated in this instrument. Due to the fact that items 7 and 8 measured the same learning objective indicator, item 7, which was invalid, eliminated was rather than corrected. In the meantime, items 5 and 11 were eliminated in order to keep the instrument consistent with the previously updated pretest.

Following the validity test, the posttest instruments' reliability was examined to ascertain the degree of internal consistency among the items. Using the Cronbach's Alpha formula and the SPSS version 26 software, the reliability test was carried out. If an instrument's alpha coefficient value is more than 0,6, it is deemed dependent since it shows that its items measure the same construct in a strong and consistent manner (Raharjanti et al., 2022).

Table 5. Post-test Reliability Test Results

Cronbach's Alpha	N of Items
0,904	12

With a total of 12 items, Table 4's data shows a Cronbach's Alpha value of 0,904. It is possible to conclude that the posttest instrument has a very high and constant level of reliability because this number is above the minimum limit of 0,6. This result demonstrates how all of the learning outcome test's items, which evaluate students' proficiency with natural disaster mitigation content, are closely connected to one another. Thus, the posttest instrument, which has undergone validation and reliability testing, is declared feasible and reliable for use in measuring learning outcomes after the application of Augmented Reality-based interactive multimedia.

Description of Student Learning Outcomes

After testing the validity and reliability of the learning outcome test instruments, the next step was to conduct a product trial to determine the effectiveness of the treatment given. The trial was conducted over two meetings. The

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first meeting was used to give students a pretest to measure their initial abilities before the treatment was applied. The second meeting was used to test the learning product and administer a posttest to determine the improvement in learning outcomes after the treatment was given. The tests conducted at the beginning and end are important instruments in experimental and classroom action research, as they form the basis for assessing the effectiveness of the treatment on changes in student learning outcomes (Baskaran et al., 2023; Dimitrov & Phillip, 2003). Yang et al. (2025) also emphasized that pre-tests and post-tests are used to see the difference in scores before and after the treatment, which is an indicator of the improvement in students' learning abilities. The results of the pre-test and post-test data description can be seen in the following table.

Table 6. Descriptive Statistics of Student Learning Outcomes

Statistik	Pretest	Posttest
Highest Score	66.67	100
Lowest Score	41,67	75
Mean	55,21	82,81
Number of Students Completing	0 students	16 students

Based on the table above, it can be seen that the highest score on the pretest was 67, while the lowest score was 42 with an average of 55,21. No students achieved the minimum passing score (KKM) of 75 on the initial test. This shows that the students' initial abilities before the treatment were relatively low. After being given treatment in the form of a learning product trial, there was a significant increase. In the posttest results, the highest score reached a perfect score of 100, while the lowest score was 75, with an average of 83. All students achieved 100% learning mastery.

This increase indicates a substantial enhancement in students' cognitive performance following the intervention. A desirable change in learning behavior as a result of an efficient learning process is indicated by a rise in the average learning score (Brunner et al., 2024; Cohen et al., 2024). Additionally, a notable improvement in students' cognitive capacities following engagement in engaging and meaningful learning activities is a sign of learning success, according to Karjanto & Acelajado (2022). As seen by the rise in average scores and the proportion of students who attained learning completeness following the action's execution, it can be said that using the created learning products effectively improves student learning outcomes.

Prerequisite Analysis Test

Before testing hypotheses, the first step that needs to be taken is to conduct a prerequisite analysis test to make sure the information satisfies the necessary statistical presumptions. This test is important so that the analysis results can be interpreted correctly and reflect the actual conditions in the field. The prerequisite test is an initial stage that serves to test the feasibility of the data before conducting inferential analysis (Shatz, 2024; Tijmstra, 2018). The normalcy test, a process that seeks to ascertain if student learning data is regularly distributed, is one of the tests utilized at this point. Therefore, one crucial step in assessing whether employing sophisticated statistical tests is feasible is the normalcy test.

Because there were less than 30 research participants, the Shapiro-Wilk test was utilized for the normalcy test in this study. This test can more precisely identify deviations from the normal distribution and is thought to be more suitable for small sample sizes. Table 6 below displays the findings of the normality test for the pretest and posttest data.

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Table 7. Results of Student Learning Outcomes Data Normality Test

Kelas	Statistic	df	sig
Pretest	0,968	16	0,65
Posttest	0,963	16	0,13

The significance value is evaluated against a threshold (α) of 0,05, which serves as the criterion for assessing normality. Data is considered to follow a normal distribution if the significance level exceeds 0.05, but is classified as non-normal if the value is below that threshold. Thus, this study is normally distributed because the significance values of the pretest data (0,65) and posttest data (0,13) are both greater than 0,05, so that the student learning outcome data meets the normality assumption and can be analyzed using parametric statistical tests.

Hypothesis Testing

To find out how student learning outcomes changed before and after the learning product was applied, hypothesis testing was carried out in this study. Because the data came from two measures of the same subjects the pretest and posttest outcomes in one class the Paired Sample t-Test was utilized in this study. After the therapy was administered, this exam was used to determine if learning outcomes had significantly improved (Coman et al., 2013; Vicol et al., 2024). Since the data satisfied the normalcy conditions prior to the t-test, parametric statistics could be used to complete the investigation. Table 7 below displays the Paired Sample t-Test findings.

Paired Samples Test									
		Paired Difference					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	PRETEST - POSTTEST	-27,60375	3,98864	0,99716	-29,72915	-25,47835	-27,682	15	0,000

The difference between the pre-test and post-test scores was -27,60, according to the Paired Sample t-test findings shown in Table 6. The two-tailed significance level of 0,000 and the t-statistic value of -27,682 were both below the 0,05 cutoff. Thus, it can be said that following the use of the educational tool, there is a statistically significant difference in the performance of the students from the pre-test to the post-test. This data demonstrates that students' learning achievement significantly improved following the intervention. This improvement provides empirical evidence supporting the effectiveness of the developed AR-based multimedia. These findings support the claims made by Hunt et al. (2025) that the effectiveness of instructional tactics is demonstrated by a notable improvement in learning outcomes following intervention. Furthermore, these results further confirm (Yusra et al., 2022) .

N-Gain analysis is used to evaluate improvements in student learning after the implementation of educational tools. N-Gain scores are obtained from a comparison of pretest and posttest results to assess the level of improvement in understanding. The N-Gain calculation data in this study are presented in **Table 8** below.

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Table 8. N-Gain Calculation Results

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Ngain_Score	16	0,50	1,00	0,6318	0,13538
Ngain_Persen	16	50,00	100,00	63,1838	13,53848
Valid N (listwise)	16				

Based on the results in Table 7, the average N-Gain score was 0,6318, equivalent to 63,18%. To determine the level of effectiveness of learning outcome improvement, the N-Gain categories proposed by Hake (1998) were used, as presented in Table 9.

Table 9. N-Gain Effectiveness Categories

N-Gain Value Range	Categories
$g \geq 0,70$	High
$0,30 \leq g < 0,70$	Medium
$g < 0,30$	Low

Based on this classification, an N-Gain score of 0,63 reflects a moderate yet meaningful improvement in conceptual understanding, which means that learning using the developed product has proven to be quite effective in improving student learning outcomes. This improvement shows that the application of learning products can help students understand the material better, increase their involvement in the learning process, and strengthen their retention of the concepts learned. These results are in line with the findings of Siregar et al. (2024), who stated that the use of technology-based learning media can increase student motivation and learning effectiveness because it provides an interactive and engaging learning experience.

Discussion

The use of interactive multimedia with the AR to disaster mitigation learning proves to have good effect on enhancing students' level of conceptual understanding. The enhancement is not only visible in the pretest and posttest scores, but also in the quality of knowledge representation that students constructed during the learning activities. The adoption of AR in this case lays new ground for the possibility of evolving disaster literacy by way of enhanced cognitive processes. The success in this study using AR lies in Mayer's Cognitive Theory of Multimedia Learning (CTML). It is believed that the best learning happens while students are exposed to dual visual and verbal information. The three dimensional models generated by AR, on one hand give plenty visual stimuli and the verbal descriptions or the written text related to these visualizations promote dual coding (Mayer, 2005). More stable knowledge integration resulted from this dual coding process may provide students with further possibility to form integrated schema about disaster phenomena.

The concept of disaster mitigation involves complex spatial elements, so understanding the concept requires adequate spatial reasoning skills. Two dimensional representations in textbooks and conventional media are often unable to describe the dynamics of natural phenomena. Three dimensional visualization through AR facilitates the observation of these phenomena from various perspectives, enabling students to construct more precise mental models. These findings are consistent with the studies by Afnan et al. (2025)which confirm that AR plays a significant role in improving spatial visualization and mental model construction in the domain of space-based learning. The power of AR in clarifying these spatial relationships is one of the factors that directly contributes to improving the understanding of disaster mitigation concepts.

Interactivity is another important component that explains the effectiveness of AR. The level of cognitive engagement increases when students interact directly with objects and disaster simulations provided by AR. Activities

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such as rotating objects, enlarging visualizations, or observing the dynamics of geological movements encourage students to experience interactive learning (Hamdi & Syukri, 2025). Such interactions increase germane cognitive load, which is the cognitive load that supports the formation of new knowledge in long-term memory. The patterns of gradually increasing student performance observed in this study correspond to a plateau model of conceptual change as defined in (Hake, 1998) model of learning gains. The differences in scores are more than simple numbers; they are an indication of whether students were able to link what they have learned to their own mental models. Moderate to high N-Gain scores suggest that AR not only offers an interesting learning environment, but also as an efficient approach to acquire long-term conceptual knowledge. This development demonstrates that high precision visualizations coupled with active participation through AR, may facilitate the development of integrative understanding for the students in the area of natural geo-processes and geo-hazards.

The mechanisms that enable pedagogical use of AR in this study are what make the application of AR in the learning process effective. Firstly, the 3D visualization of objects displayed by AR boosts students' spatial ability and makes them learn disaster knowledge in a more intuitive way. In addition, the interactivity of AR technology also promotes active learning, students not only passively receive information, but also participate in the process of researching phenomena directly. Thirdly, the media's immersiveness also enhances learning engagement, which has been shown to aid concept retention as well as material elaboration. The result is consistent with the studies of Sudrajat et al. (2023); Ernawati & Maulidna, (2023); Fauziah et al. (2025) which identify that AR activity in geography teaching supports the improvement of learner's outputs by offering a space that is synonymous with and simplify spatial visualization.

The implications of this research show that AR can bridge the gap between abstract concepts and complex geospatial realities. Deep visual representations, effective dual-coding mechanisms, increased cognitive engagement, and AR's ability to support spatial reasoning position this technology as a strategic learning medium for improving disaster literacy. This effectiveness confirms that the integration of AR in geography learning is not merely a technological innovation, but an evidence-based pedagogical approach that contributes significantly to the quality of learning.

CONCLUSION

The findings of this study demonstrate that AR-based interactive multimedia significantly improves students' learning outcomes in the Natural Disaster Mitigation topic. The substantial increase from the pretest to posttest scores confirms the effectiveness of AR in presenting abstract geographical concepts in an interactive and engaging manner. This study highlights the potential of AR to enhance cognitive engagement, spatial understanding, and authentic learning experiences in geography classrooms. However, this study involved a small sample size and lacked a control group, which limits generalizability. Future research is recommended to use larger samples, comparative designs, and qualitative data to explore students' perceptions and engagement processes.

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