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The Effectiveness of Science Learning Based on Volcanic Activity Data in Enhancing Students' Disaster Literacy in North Maluku

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Abstract

This study aims to analyze the effectiveness of science learning based on volcanic activity data in improving students' disaster literacy in North Maluku. The study employed a quasi-experimental method using a *pretest–posttest control group design*. The participants were Grade 10 senior high school students, divided into an experimental group and a control group. The experimental group was taught using authentic data on volcanic activity, such as data from Mount Ibu and Mount Dukono, while the control group received conventional instruction. The results revealed a significant improvement in disaster literacy among students in the experimental group, with an N-gain score of 0.68 (moderate–high category), compared to 0.32 (low–moderate category) in the control group. The results of the t-test showed a significance value of 0.001 ($p < 0.05$), indicating a statistically significant difference between the two groups. Therefore, science learning based on volcanic activity data is effective in enhancing students' disaster literacy.

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INTRODUCTION

Indonesia is a country with a high level of disaster vulnerability due to its location along the Pacific *Ring of Fire* (Varlamis, 2025). One of the regions with particularly high risk is North Maluku, which is characterized by intensive volcanic activity and the potential for disasters such as eruptions, ashfall, and pyroclastic flows (Darling-Hammond et al., 2020). This situation necessitates mitigation strategies that are not only structural but also focus on building community capacity through education (Yoshinori et al., 2024).

In line with this, disaster education has evolved as an important field of study in building resilient communities (Darling-Hammond et al., 2020; Yoshinori et al., 2024). Generally, four main trends can be observed in previous research. First, studies highlight the low level of students' preparedness for disasters, which is linked to the limited integration of disaster-related content in the formal curriculum. These findings indicate a gap between disaster mitigation needs and actual classroom practices (Muhammad & Idrus, 2024).

Second, research that develops the integration of disaster education into science lessons through contextual and phenomenon-based approaches (Bachri et al., 2023). These studies suggest that linking scientific concepts with real-world situations can significantly enhance students' disaster literacy and create more meaningful and applicable learning experiences (Desilia et al., 2023).

Third, research that identifies various implementation challenges, such as limited teaching materials, low teacher readiness, and the insufficient use of authentic data in learning (Wahyu Berlianawati et al., n.d.) However, the use of real data—such as volcanic activity data—has great potential to improve students' critical thinking and understanding of disaster risks (Arumning Tyas, 2021; Dinda Putri et al., 2026)

Fourth, studies emphasize school-based approaches, such as disaster psychoeducation, which have proven effective in increasing students' awareness, attitudes, and preparedness (Asrizal, 2020). This emphasizes that disaster education functions not only as knowledge transfer but also as a means of shaping adaptive behaviors toward disaster risks (Achmad et al., 2025; Jannah, 2021).

Although these approaches have been developed, there remains a significant research gap. Most studies still focus on conceptual integration or general interventions but have not specifically optimized the use of local volcanic activity data as a contextual learning resource in science education. Furthermore, studies that test the effectiveness of such approaches in improving disaster literacy in high-risk regions like North Maluku are still limited.

Therefore, this study offers novelty by developing and testing science learning based on local volcanic activity data to enhance students' disaster literacy. Specifically, this research aims to analyze the effectiveness of this approach in the context of education in disaster-prone areas.

RESEARCH METHOD

This study uses a quantitative approach with a quasi-experimental design in the form of a pretest–posttest control group design. This design is used to test the effectiveness of science learning based on volcanic activity data in improving students' disaster literacy by comparing the results before and after the treatment in the experimental and control groups (Achmad et al., 2025; Asshiddiqi et al., 2021; Supriyadi et al., 2020)

Schematic representation of the research design is as follows:

Experimental Group: O_1 X O_2

Control Group: O_1 – O_2

Description: O_1 = Pretest (initial disaster literacy test), O_2 = Posttest (final disaster literacy test), X = Treatment (volcanic activity data-based learning) – = Conventional learning

The research subjects consisted of 60 students from grade X at SMA Negeri 6, Tidore Islands, who were divided into two groups: the experimental group (n = 30) and the control group (n = 30). The sampling technique used was purposive sampling, considering the equivalence of students' initial abilities based on the pretest results.

The research procedure was carried out in three stages: preparation, implementation, and evaluation. In the preparation stage, the researcher developed the volcanic activity data-based learning materials and conducted instrument validation through expert judgment (Estri et al., 2021; Tyas et al., 2023). The implementation stage began with administering the pretest to both groups, followed by the application of volcanic activity data-based learning in the experimental group, while the control group received conventional learning. After the treatment, both groups were given the posttest. The evaluation stage involved data analysis

to measure improvements in disaster literacy and differences between the groups (Putu Eka Suarmika et al., 2025; Wahyuningtyas et al., 2021).

The research instruments include a disaster literacy test, a student response questionnaire, and a learning activity observation sheet. The test consisted of 20 multiple-choice items covering indicators of volcanic concept understanding, eruption data analysis, and disaster mitigation. The validity of the instruments was tested through content validity by experts and empirical validity using Pearson correlation, while reliability was tested using Cronbach's Alpha with a criterion of $\alpha > 0.70$.

Data analysis included the N-gain test to measure improvements in learning outcomes, prerequisite tests including normality (Kolmogorov-Smirnov) and homogeneity (Levene's test), and hypothesis testing using independent samples t-test to determine significant differences between the experimental and control groups (Atmojo et al., 2018; Saregar et al., 2025; Sari et al., 2022). Additionally, descriptive analysis was used to describe students' learning outcomes and their responses to the learning process.

RESULT AND DISCUSSION

Based on the research data, there was an improvement in disaster literacy ability in both groups, but the experimental group showed a significantly better performance. The comparison of pretest, posttest, and N-gain results is presented in Table 1.

Table 1. Comparison of Disaster Literacy Scores and N-Gain

Class	Mean Pretest	Mean Posttest	N-Gain	Category
Experimental	45	85	0.68	Moderate–High
Control	47	65	0.32	Low–Moderate

In addition to score improvement, the analysis of data distribution through standard deviation indicates differences in students' understanding dynamics. For Experimental Class, The standard deviation decreased from 12.4 to 8.1, indicating that students' understanding became more evenly distributed after the intervention. For Control Class, The standard deviation remained relatively constant at 11, suggesting that the variation in students' understanding remained high. The results of the Kolmogorov–Smirnov and Levene's tests indicate that the data are normally distributed and have homogeneous variance (Sig. > 0.05), thus meeting the assumptions for parametric statistical analysis.

Table 2. Summary of Prerequisite Tests

Test Type	Variable/Group	Sig. Value	Description
Normality	Experimental	0.087	Normal
	Control	0.091	Normal
Homogeneity	Data Variance	0.214	Homogeneous

Table 2 summarizes the prerequisite test results, indicating that the data meet the required assumptions for further analysis. The normality test shows that both the experimental group (Sig. = 0.087) and the control group (Sig. = 0.091) are normally distributed. In addition, the homogeneity test yields a significance value of 0.214, confirming that the data variance is homogeneous. Based on these results, hypothesis testing was conducted using an independent samples t-test to examine the significance of differences

between the two groups. The findings reveal a significance value (Sig. 2-tailed) of 0.001, which is less than 0.05, indicating a statistically significant difference. Furthermore, the obtained t-value of 4.87 exceeds the t-table value of 2.00, reinforcing this conclusion. The effect size, calculated using Cohen's d, is 0.85, which falls into the large effect category. This suggests that the intervention has a strong practical impact on improving disaster literacy.

The research results show that volcanic activity data-based learning is significantly more effective than conventional learning in improving students' disaster literacy. This is evident from the difference in N-gain values between the experimental group (0.68; moderate–high category) and the control group (0.32; low–moderate category), supported by an effect size of 0.85, which is classified as a large effect. These findings suggest that intervention not only has statistical significance but also a strong practical impact.

These results align with previous studies (Atmojo et al., 2018; Naufal Azhar et al., 2025; Tyas et al., 2021) which indicate that integrating disaster education into science learning through contextual approaches can significantly improve students' disaster literacy. However, this study makes a further contribution by showing that using authentic volcanic activity data not only improves learning outcomes but also strengthens the uniformity of student understanding, as demonstrated by the decrease in standard deviation in the experimental class from 12.4 to 8.1. Thus, data-based learning is effective not only for high-ability students but also helps lower-ability students achieve a better understanding.

From a theoretical perspective, this improvement can be explained through the lens of constructivism, where knowledge is built through direct interaction with real-world phenomena (Saregar et al., 2025; Supriyadi et al., 2020). Using volcanic activity data allows students to construct understanding based on empirical evidence, rather than passively receiving information. This also supports findings from Sari et al. (2022) and Dewi et al. (2019), which state that using real-world data in science learning enhances critical thinking and data analysis skills (Wahyuningtyas et al., 2021). In this study, students not only understood volcanic concepts but were also able to interpret eruption trends and relate them to potential disaster risks (Putu Eka Suarmika et al., 2025).

Moreover, in terms of student engagement, the study revealed that the learning activity rate in the experimental class reached 85% (very active category), higher than the control class, which only reached 60% (moderately active category). This finding supports the argument that data-based learning encourages active learning, where students take an active role in the learning process. This contrasts with conventional learning, which tends to be teacher-centered, limiting student exploration and participation. This finding is consistent with the work of Darling-Hammond et al. (2020), which emphasizes that learning based on real-life experiences increases student engagement and depth of understanding (Estri et al., 2021; Saregar et al., 2025; Setiawan et al., 2017; Wahyuningtyas et al., 2021).

However, the effectiveness of this learning approach is not independent of the local context of the study. Students in Maluku Utara live in an environment with high volcanic activity, so the data used in the learning process has direct relevance to their lives. This contextual factor strengthens the meaning of the learning process and boosts students' intrinsic motivation. In other words, the success of this approach is determined not only by

the method but also by the alignment between the learning material and the students' environmental reality. This aspect has not been widely explored in previous research, which generally uses contextual approaches without focusing on specific local data (Dinda Putri et al., 2026).

On the other hand, while the results show high effectiveness, there are several critical implications that need to be addressed. First, implementing data-based learning requires teachers to be ready to manage and present the data pedagogically. This is in line with the findings of Dinda Putri et al. (2026) and Desilia et al. (2023), which identify teacher competence and teaching materials as key challenges in disaster education. Second, the availability and access to valid volcanic activity data are also crucial factors for the success of this learning approach (Yoshinori et al., 2024).

Thus, this study not only confirms the effectiveness of contextual approaches in disaster education but also expands them through the integration of volcanic activity data as an authentic learning resource. This approach has been shown to simultaneously improve learning outcomes, increase the uniformity of understanding, enhance student engagement, and develop data analysis skills. Therefore, volcanic activity data-based learning can be considered an innovative strategy for improving disaster literacy, especially in disaster-prone areas.

CONCLUSION

This research concludes that science learning based on volcanic activity data is significantly effective in improving students' disaster literacy. The effectiveness is demonstrated by the higher learning outcomes in the experimental group compared to the control group, the N-gain values in the moderate–high category, and statistical test results showing significant differences between the groups. Moreover, the large effect size indicates that the learning intervention is not only statistically significant but also has a strong practical impact. Other findings show that this approach can increase student engagement, promote data analysis skills, and reduce the gap in understanding between students. Theoretically, the results of this study strengthen the constructivist approach and inquiry-based learning by confirming that using authentic data as a learning resource can simultaneously improve conceptual understanding and disaster literacy. This research also extends previous studies by demonstrating that the integration of local volcanic activity data is not only contextually relevant but also plays an important role in building connections between scientific concepts and students' real-world environments.

Practically, these findings imply that data-based learning can be considered an innovative strategy in disaster education, especially in disaster-prone areas like North Maluku. The implementation of this model has the potential to more effectively enhance student preparedness, as the learning process focuses not only on cognitive aspects but also on raising awareness and shaping attitudes towards disaster risks. Therefore, teachers and educational policymakers should consider integrating real data into the curriculum and developing contextual teaching materials. However, this study has limitations, including the sample size and the specific regional context, as well as the dependency on teachers'

readiness to manage data-based learning. Therefore, future research is recommended to test this model at different educational levels and in different regions, integrate digital technology into volcanic data processing, and explore its impact on other aspects such as critical thinking skills, decision-making, and long-term disaster preparedness.

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AUTHOR CONTRIBUTIONS

This section describes the roles of each author in conducting the research and writing the article. Fitri contributed to the research design, data analysis, and manuscript writing. Agus was responsible for data collection and field implementation. Faradina contributed to instrument development and data validation. Sumarni assisted in data analysis and interpretation of results. Fazrul contributed to manuscript revision and final editing.

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