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Disaster Learning Based on Local Wisdom Through a Simulation Learning Model Toward Students' Disaster Preparedness in the Small Volcanic Island of Ternate

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ABSTRACT
Ternate City is classified among the 170 regencies and cities identified as priority sites for disaster risk reduction by the Indonesian government, as designated by the National Disaster Management Agency (BNPB). This categorization is attributed to the geographic characteristics of Ternate Island, which is characterized as a small volcanic island featuring the active Gamalama Volcano, thereby presenting a significant disaster risk. These circumstances cause local residents, specifically junior high school students residing within the Gamalama Volcano Disaster-Prone Zone (Kawasan Rawan Bencana-KRB), to be particularly vulnerable to disasters. Therefore, the implementation of disaster education that incorporates the local wisdom of Ternate through a simulation-based learning model is crucial to enhance students' preparedness and mitigate risks during potential disaster occurrences. This study aims to identify the level of disaster preparedness between an experimental group taught using a simulation learning model integrated with local wisdom-based disaster education and a control group taught using conventional learning. It also aims to compare the preparedness levels between both groups. The study employed a quasi-experimental method using a posttest-only control group design. The sample consisted of 192 students selected using cluster random sampling, consisting of 96 students in the experimental group and 96 students in the control group. Data analysis involved both descriptive quantitative analysis and comparative analytical techniques. The results indicate that the preparedness level of the experimental group was classified as "very ready," with an index of 87.02. In contrast, the control group was categorized as "ready," with an index of 73.58. Furthermore, the comparative analysis reveals that Sig. (2-tailed) = 0.000 < 0.05, suggesting a statistically significant difference between the two groups; hence, H0 is rejected while Ha is accepted. These findings confirm that the simulation learning model integrated with local wisdom-based disaster education significantly enhances student disaster preparedness in comparison to conventional educational methods.

INTRODUCTION

Ternate City is an archipelagic region located on a small volcanic island with Mount Gamalama, which remains active to this day. The total land area of Ternate Island is 101.67 km², inhabited by 204,920 people, of which 90% reside on Ternate Island (Badan Pusat Statistik Kota Ternate, 2024). Its limited land area and high population density place the community living on this small volcanic island at high risk and vulnerability to the threats posed by potential eruptions of Mount Gamalama (Hidayat et al., 2023; Hidayat et al., 2020).

Ternate City is one of the 170 regencies and cities designated as priority locations for reducing the Disaster Risk Index by the government through BNPB in the National Disaster Management Plan (RENAS PB) for 2025–2029 (Peraturan BNPB No. 1 Tahun 2025). This is defined because Ternate City has a high Disaster Risk Index (DRI) for multi-hazard disaster events, including the eruption of Mount Gamalama (BNPB, 2023). The high DRI reflects the low level of community preparedness in facing disasters. Therefore, efforts to reduce the DRI through increasing community preparedness are anticipated to directly contribute to the reduction of disaster risk both within Ternate City and on a national scale.

The volcanic eruptions of Gamalama present both direct (primary) and indirect (secondary) hazards. Primary hazards include ejection of loose materials ranging from ash to bombs, lava flows, and pyroclastic density currents, while secondary hazards include lahar flows and volcanic tsunamis (Hidayat et al., 2020; Marfai et al., 2019). One of the sectors impacted by both primary and secondary hazards is the formal education sector. Schools located in the Gamalama Volcano Disaster-Prone Zone (KRB) are highly vulnerable, especially junior high school students who are classified as a vulnerable group during disaster events (UU RI No. 24 Tahun 2007). Therefore, it is essential to increase their disaster preparedness capacity.

Disaster preparedness pertains to the proactive measures undertaken prior to the occurrence of a disaster, aimed at minimizing casualties and material losses. According to (Rañeses et al., 2018; Sutton & Tierney, 2006; Carter, 1992), preparedness is knowledge and capacity developed by governments, institutions, communities, and individuals to effectively anticipate, respond to, and recover from the impacts of current and future disasters. Thus, students must strengthen their disaster knowledge, as higher levels of disaster literacy correlate with improved preparedness (Hidayat et al., 2022; Lukman et al., 2021; Lukman & La Masinu, 2020).

Findings Lukman (2021), Lukman et al. (2021), Lukman & La Masinu (2020) indicate that before the implementation of learning interventions, the preparedness levels of students from various schools did not achieve the "very ready" classification concerning responses to the Gamalama volcanic disaster. The comprehension of disaster-related phenomena among students is primarily derived from personal experiences encountered during actual disaster occurrences. Therefore, the implementation of learning interventions within schools is essential to strengthen preparedness, as the failure of such measures may lead to severe consequences during volcanic eruptions.

The disaster education for students is most naturally acquired through the local wisdom embedded in their immediate surroundings. Local wisdom constitutes a comprehensive formulation of knowledge, belief, as well as customary practices and ethics that lead human behavior to live in the community (Marfai, 2022). In the context of disaster risk reduction, such indigenous knowledge systems have demonstrably helped reduce casualties, as exemplified by the Smong oral tradition on Simeulue Island, Aceh (Ramli et al., 2024; Sutton et al., 2021; Gadeng et al., 2018; Rahman et al., 2018), and have informed locally grounded disaster communication practices (Fakhriati et al., 2023). Beyond casualty mitigation, local wisdom has also been shown to strengthen disaster preparedness more broadly (Roy et al., 2026; Utomo et al., 2026; Rusydi et al., 2023; Koopman, 2023; Hanif et al., 2022). These findings underscore the urgency of integrating local wisdom into efforts aimed at improving student preparedness in the face of Mount Gamalama's volcanic hazards.

Several forms of Ternate community local wisdom related to volcanic mitigation, based on research Amin et al. (2024), include local knowledge-based mitigation and ritual-based mitigation. Ritual-based mitigations include *kololi kie*, *fere kie*, and *doa kie*, while local knowledge-based mitigations involve three phases: pre-eruption, emergency response, and post-eruption. As local wisdom varies across regions, instructional materials must incorporate relevant local values into disaster education. According to Rahmat et al. (2024) local wisdom-based disaster education effectively reduces vulnerability and increases preparedness.

In learning, integrating Ternate local wisdom into disaster education must be supported by an appropriate learning model that organizes instructional processes to achieve learning goals. The simulation learning model aligns with disaster-related learning content. Simulation learning is an instructional strategy used to strengthen real-life experiences by replicating real-world conditions (Rifky et al., 2024; Marzuki, 2024). Moreover, simulation learning is effective for increasing knowledge (Putri et al., 2024; Lukman & Muhammad, 2023; Lukman et al., 2023), and disaster preparedness (Muhlis et al., 2024; Idrus et al., 2019). According to Joyce et al. (2016) the simulation learning model consists of four instructional steps: orientation, participatory practice, simulation execution, and participant interview.

Therefore, it is worth noting that local wisdom manifests in distinctly different forms across regions, particularly in the domain of volcanic disaster mitigation. Prior studies have tended toward partial approaches: some examined the application of simulation learning models to students' preparedness competencies (Muhlis et al., 2024; Lukman & Muhammad, 2023; Lukman et al., 2023; Idrus et al., 2019), explored Ternate's local wisdom in mitigating Mount Gamalama eruptions (Amin et al., 2024), investigated how local wisdom shapes disaster preparedness more broadly (Roy et al., 2026; Utomo et al., 2026; Rusydi et al., 2023; Koopman, 2023; Hanif et al., 2022), or assessed baseline preparedness levels among students facing Gamalama's volcanic threats (Hidayat et al., 2023; Hidayat et al., 2022; Lukman et al., 2021; Lukman & La Masinu, 2020). However, only a few published studies have yet sought to integrate the simulation learning model with local wisdom-based disaster education within an experimental design. This study, therefore, aims to examine student preparedness levels between an experimental group that received the simulation learning model integrated with local wisdom-based disaster education and a control group that received conventional instruction, as well as to compare preparedness levels between the two groups.

RESEARCH METHODS

This study employed a quasi-experimental method. This method is part of a quantitative approach characterized by the presence of a control group (Tong et al., 2022; Thyer, 2012). The quasi-experimental design used in this research was a posttest-only control design. The research was conducted in four junior high schools, namely SMP Negeri 5 Kota Ternate, MTs Negeri 1 Kota Ternate, SMP Negeri 2 Kota Ternate, and Madrasah Tsanawiyah Swasta Pengembangan Kulaba. All research locations were located within the Disaster-Prone Zone (KRB) of the Gamalama Volcano on Ternate Island. The study population consisted of 651 eighth-grade students from the four schools. With a 10% margin of error, the total sample size was 192 students. Of these, 96 students formed the experimental group and 96 students formed the control group. Sample determination was based on the Isaac and Michael sampling table (Elfira et al., 2024; Baazeem & Qaffas, 2020; Sugiyono, 2019; Isaac & Michael, 1995).

The experimental group received the simulation learning model integrated with local wisdom-based disaster education, which included: class VIII-A of SMP Negeri 5 Kota Ternate (24 students), class VIII-A of MTs Negeri 1 Kota Ternate (24 students), class VIII-A of SMP Negeri 2 Kota Ternate (24 students), and class VIII-A of Madrasah Tsanawiyah Swasta Pengembangan Kulaba (24 students). Meanwhile, the control group received conventional learning, consisting of: class VIII-B of SMP Negeri 5 Kota Ternate (24 students), class VIII-B of MTs Negeri 1 Kota Ternate (24 students), class VIII-B of SMP Negeri 2 Kota Ternate (24 students), and class VIII-B of Madrasah Tsanawiyah Swasta Pengembangan Kulaba (24 students). The sampling technique used to determine both groups was cluster random sampling.

The adoption of a quasi-experimental design carries a risk of self-selection bias, given that group assignment was not randomized at the individual level. To minimize this potential source of bias, sampling was conducted through cluster random sampling, with deliberate attention to ensuring baseline equivalence across groups. Equivalence was controlled through several design-level decisions: matching grade levels, school environments, and instructional durations, and administering an identical preparedness measurement instrument to both groups. Under these conditions, observed differences in preparedness between the experimental and control groups may reasonably be attributed primarily to the instructional intervention. The research location is shown in Figure 1 below.

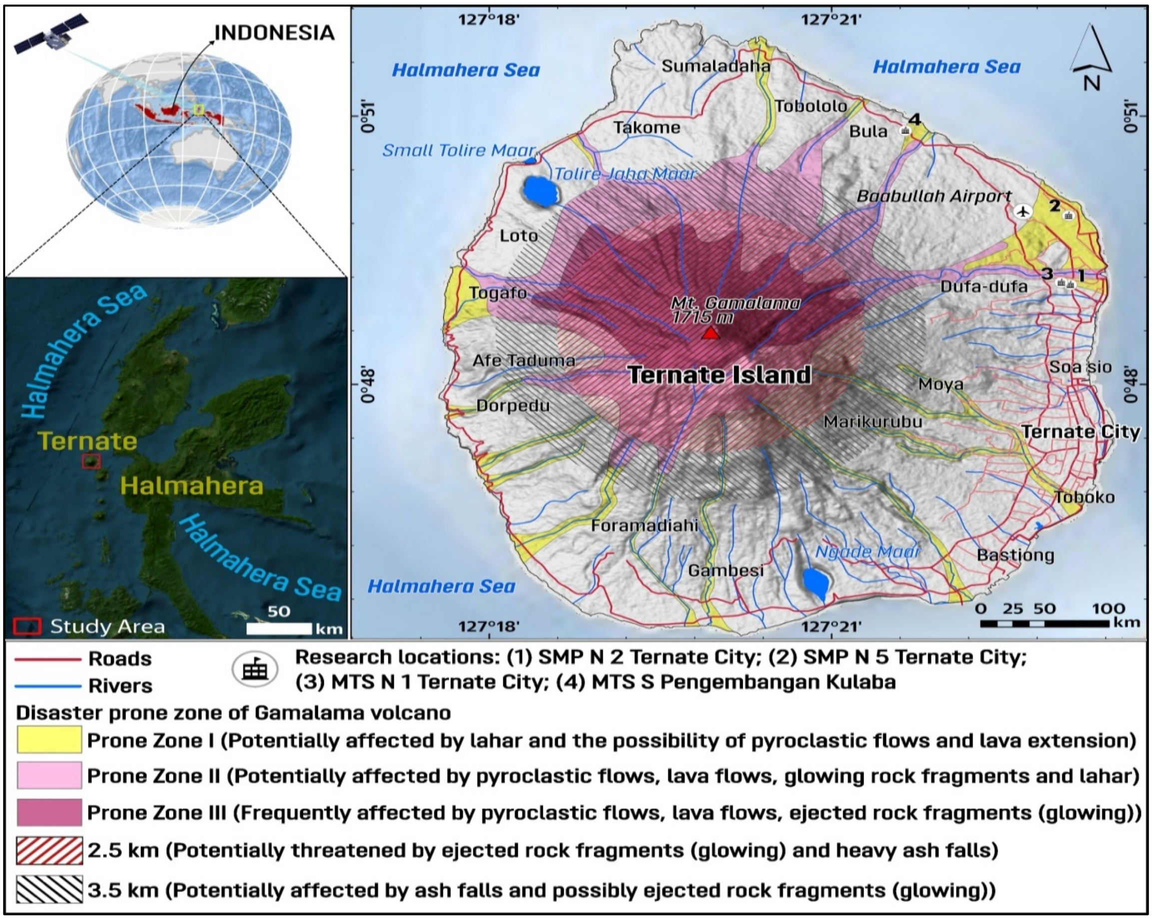

Figure 1. Research Locations and Volcanic Disaster-Prone Areas
(Source: Data Analysis, 2025)

Research Instrument

The research instrument used in this study was a questionnaire designed to measure variables related to student preparedness in facing the Gamalama volcanic disaster. The questionnaire was developed based on four preparedness indicators for school communities in anticipating natural disasters (Lukman, 2021; LIPI and UNESCO/ISDR, 2006). The indicators included knowledge and attitudes, emergency response plan, disaster warning system, and resource mobilization. The instrument was validated by experts and tested for validity and reliability. Pearson correlation was used for the validity test, while Cronbach's alpha was used for the reliability test, administered to 24 respondents at a 5% significance level. The obtained correlation table value was 0.404. The validation results indicated that all questionnaire items were valid, as the calculated correlation values for all items exceeded the table value. Meanwhile, the reliability test showed Cronbach's alpha of 0.789 > 0.60, and also greater than the correlation table value of 0.404, indicating that the instrument was reliable. Responses were measured using a Likert scale ranging from strongly positive to strongly negative, with the following scoring: strongly agree (4), agree (3), disagree (2), and strongly disagree (1). The student preparedness questionnaire instrument is presented in Table 1.

Table 1. Student Preparedness Instrument

Variable	Indicator	Sub-Indicator	Item Number	
			Positive	Negative
Preparedness	Knowledge and attitude	Definition of natural disaster	1,2	
		Causes of volcanic disasters and resulting hazards	3, 4	5,6,7,8
		Types, forms, sources, magnitude, and disaster locations	9,10,11	12,13,14
		Attitude toward disaster risk	15,16,17,18, 19,20	21,22,23
	Emergency response plan	Evacuation plan	24	25,26
		Emergency drill and simulation	27,28	29
	Disaster warning system	Identifying disaster warning signs	30,31	32,33
	Resource mobilization	Human resources (student participation in disaster-related activities)	34	35,36

(Source: Data Analysis, 2025)

Data Analysis

Data analysis consisted of descriptive quantitative analysis and comparative analysis. Descriptive quantitative analysis was used to determine students' disaster preparedness levels. Preparedness levels were obtained from the combined index scores of each preparedness indicator. To calculate the index score for each indicator, the following formula was used:

$$\text{Index} = \frac{\text{Total score of indicator}}{\text{Maximum score of indicator}} \times 100$$

After obtaining the preparedness index score for each indicator, the combined preparedness index was calculated using the formula developed (LIPI and UNESCO/ISDR, 2006), as follows:

$$\text{Student Preparedness Index} = 0{,}64 \times \text{KA Index} + 0{,}17 \times \text{EP Index} + 0{,}11 \times \text{WS Index} + 0{,}08 \times \text{RMC Index}$$

The results of the combined index analysis obtained the student preparedness index value, which was then converted based on the index value category in Table 2 as follows.

Table 2. Student Preparedness Categories

No	Index Range	Category
1	80 - 100	Very Ready
2	65 – 79	Ready
3	55 – 64	Almost Ready
4	40 – 54	Less Ready
5	< 40 (0 – 39)	Not Ready

(Source: LIPI and UNESCO/ISDR, 2006)

Comparative analysis aimed to determine the difference in preparedness levels between the experimental group that received simulation learning integrated with local wisdom-based disaster education and the control group that received conventional learning. The independent sample t-test with a significance level of 0.05 was used with the help of SPSS version 20. The hypothesis criteria were as follows:

1. If the Sig. (2-tailed) value is > 0.05, then H0 is accepted, and Ha is rejected, which means there is no difference in the disaster preparedness level between the experimental group that received the simulation learning model integrated with local wisdom-based disaster education and the control group that received conventional learning.
2. If the Sig. (2-tailed) value is < 0.05, then H0 is rejected, and Ha is accepted, which means there is a difference in the disaster preparedness level between the experimental group that received the simulation learning model integrated with local wisdom-based disaster education and the control group that received conventional learning.

RESULTS AND DISCUSSION

This study had two main objectives: first, to determine the level of disaster preparedness among students in the experimental group who received simulation learning integrated with local wisdom-based disaster education compared with the control group that received conventional learning (lecture method); and second, to evaluate and compare the preparedness levels of both groups.

Preparedness Level of Junior High School Students in the Control Group in Facing the Eruption of Gamalama Volcano

The analysis of student preparedness levels was obtained from the control group after receiving conventional learning. The results are presented in Table 3.

Table 3. Results of the Preparedness Level of Students in the Control Group

Indicator	Frequency: Very Ready	Ready	Almost Ready	Less Ready	Not Ready	Total Students	Preparedness Index Per Indicators	Preparedness Category
Knowledge and attitude	31	37	19	9	0	96	74,59	Ready
Emergency response plan	28	35	17	16	0		71,18	Ready
Disaster warning system	40	24	24	8	0		72,27	Ready
Resource mobilization	35	33	21	7	0		72,40	Ready
Student Preparedness Index							73,58	Ready

(Source: Data Analysis, 2025)

As shown in Table 3, the 96 students in the control group were categorized as "ready", with an overall preparedness index of 73.58. Index scores across all four preparedness indicators also fell within the "ready" category: knowledge and attitudes scored 74.59, resource mobilization 72.40, disaster warning systems 72.27, and emergency response planning 71.18. These findings collectively indicate that students generally possessed adequate preparedness for a potential Mount Gamalama eruption.

Examining the knowledge and attitudes indicator more closely, 31 students were classified as "very ready", and 37 students were classified as "ready", suggesting that the majority had developed sound knowledge and attitudes toward the volcanic threat. Nevertheless, 19 students fell into the "almost ready" category, and 9 students were classified into "less ready", groups that had yet to demonstrate a clear understanding of hazard zones or of the appropriate actions to take during an eruption. Within the emergency response planning indicator, 28 students were classified as "very ready", and 35 students were classified as "ready", while 17 students were "almost ready", and 16 students were classified as "less ready", students in the latter categories lacked familiarity with emergency procedures such as evacuation routes and temporary assembly points for a Gamalama eruption.

Regarding the disaster warning systems indicator, 40 students were classified as "very ready", and 24 students were classified as "ready", yet 24 remained "almost ready", and 8 students were classified as "less ready". These students had not yet developed a reliable ability to recognize early warning signs, including the use of local environmental knowledge to interpret natural signals. On the resource mobilization indicator, 35 students were classified as "very ready", and 33 students were classified as "ready", while 21 students were classified as "almost ready", and 7 students were classified as "less ready", students in the later categories had not fully appreciated the importance of capacity-building through socialization activities and simulation drills in preparing for Gamalama's eruption potential.

Preparedness Level of Junior High School Students in the Experimental Group in Facing the Eruption of Gamalama Volcano

Preparedness scores for the experimental group were obtained after receiving the simulation learning model integrated with local wisdom-based disaster education. The results are presented in Table 4.

Table 4. Results of the Preparedness Level of Students in the Experimental Group

Indicator	Frequency					Total Students	Preparedness Index Per Indicators	Preparedness Category
	Very Ready	Ready	Almost Ready	Less Ready	Not Ready			
Knowledge and attitude	71	16	9	0	0	96	88,49	Very Ready
Emergency response plan	66	18	12	0	0		85,03	Very Ready
Disaster warning system	62	23	11	0	0		85,16	Very Ready
Resource mobilization	52	32	12	0	0		82,29	Very Ready
Student Preparedness Index							87,02	Very Ready

(Source: Data Analysis, 2025)

According to the data presented in Table 4, the preparedness level of students in the experimental group, consisting of 96 students, was categorized as "very ready," with a preparedness index score of 87.02. This index score resulted from the combined contribution of each preparedness indicator. When examined across the four measured indicators, all were categorized as "very ready." The knowledge and attitude indicator obtained the highest index score of 88.49, followed by the disaster warning system indicator with a score of 85.16, the emergency response plan indicator with 85.03, and the resource mobilization indicator with a score of 82.29.

A total of 87 students (90.62%) were classified within the "very ready" and "ready" categories for the knowledge and attitude indicator, indicating that treatment using a simulation learning model integrated with local wisdom-based disaster education was effective in improving students' knowledge and actions in responding to the Gamalama volcanic eruption. Meanwhile, 84 students (87.5%) were classified as "very ready" or "ready" in the emergency response plan indicator, indicating improved ability to perform emergency response procedures as a result of hands-on simulation experience. For the disaster warning system indicator, 85 students (88.54%) were classified as "very ready" or "ready," demonstrating that the simulation enhanced students' sensitivity to early warning signs of natural hazards. Meanwhile, in the resource mobilization indicator, 84 students (87.5%) were classified as "very ready" and "ready" categories, indicating an improvement in students' capacity related to disaster mitigation through local wisdom-based learning and simulation activities**.**

Findings from the experimental group indicate that the simulation learning model integrated with local wisdom-based disaster education was effective in improving student preparedness relative to the control group. This effectiveness is closely tied to the model's systematic instructional steps, which actively engaged students throughout the learning process. The model began with an orientation phase, designed to build students' foundational understanding of the learning objectives, content, and procedural flow. At this stage, the teacher presented disaster mitigation material centered on the Gamalama eruption, contextualized through Ternate's local wisdom as a preparedness-enhancing framework, and clarified the conceptual and procedural underpinnings of the simulation model. Students engaged actively by attending to the teacher's explanations and raising questions wherever content or procedures remained unclear, thereby establishing shared understanding prior to simulation activities.

The next step, participatory practice, served as a preparatory phase before the full simulation was conducted. During this stage, the teacher developed and communicated a simulation scenario incorporating the Standard Operating Procedures (PROTAP) for emergency evacuation in response to a Gamalama eruption within the school environment, covering recognition of volcanic hazard signage, evacuation routes, early warning signals, and temporary assembly points. Students were then asked to perform a brief initial rehearsal of the PROTAP in preparation for the actual simulation.

The third step, simulation execution, constituted the core of the learning model. At this stage, students carried out the evacuation simulation in accordance with the established PROTAP. The teacher assumed the role of supervisor and evaluator throughout the process; should any procedural deviation arise, the teacher temporarily halted the activity to provide clarification and correction before resuming. The simulation could be repeated as many times as needed until the entire sequence was performed in full compliance with the prescribed procedures. Through this step, students gained direct experiential learning under conditions that closely mirrored an actual disaster scenario.

The final step, participant interview, was aimed at reflecting on the entire learning experience. During this step, the teacher elicited students' perceptions, experiences, and difficulties encountered during the simulation, then revisited the content by drawing comparisons between the simulation activities and real disaster conditions, anchoring the discussion in disaster education theory. Together, teacher and students evaluated the simulation and, where necessary, redesigned it collaboratively. Conclusions were subsequently drawn from the full learning sequence, and the teacher closed the session by informing students of an upcoming post-test evaluation. Through this simulation-based approach, students not only acquired theoretical knowledge of natural disaster mitigation but also developed experiential understanding through direct practice, such as emergency evacuation drills for a Gamalama eruption. As Hawsawi et al. (2025), Tasantab et al. (2021), stated that improvements in disaster knowledge and skills of this kind are attributable to the first-hand experience students gain through the simulation learning model.

The experiential learning derived from the simulation model assumed even greater significance when coupled with the integration of local wisdom as the contextual framework for disaster education. The incorporation of Ternate's local wisdom into the Gamalama eruption mitigation curriculum encompassed ritual-based mitigation practices, including *kololi kie, fere kie,* and *doa kie,* as well as knowledge-based mitigation drawing on the reading of natural signs, such as physical changes in Tolire Besar Lake and Tolire Kecil Lake, the emergence of *tulfugu*, and shifts in animal behavior. The curriculum additionally integrated the use of the traditional *marimbati* evacuation route and the communal labor practice of *bari* (mutual assistance) in the post-eruption recovery phase. This integration of local wisdom values substantively strengthened student preparedness: by rendering disaster education more contextually resonant with students' lived experiences, it also directly trained them in locally appropriate mitigation practices. Lestari et al. (2025) and Widyawardana et al. (2021) affirm that local wisdom-based disaster education enhances student preparedness precisely because it is more contextual and directly relevant to students' everyday lives.

Comparison of Disaster Preparedness Levels Between Experimental and Control Groups

The data on disaster preparedness levels between the experimental group, which received treatment using a simulation learning model integrated with local wisdom-based disaster education, and the control group, which received treatment using conventional learning, were compared to determine whether there was a significant difference in effectiveness between the two groups. However, before comparing the data from the experimental group and the control group, the data from both groups had to be normally distributed as a requirement for using the independent sample t-test. Meanwhile, if the variance of the data between the two groups was not homogeneous, the independent sample t-test could still be carried out. However, the decision-making process would be based on the results presented in the SPSS output table under Equal variances not assumed. The results of the normality test are presented in Table 5.

Table 5. Normality Test Results

	Groups	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Disaster	Experimental	,084	96	,094	,984	96	,310
Preparedness	Control	,073	96	,200*	,983	96	,232

(Source: Data Analysis, 2025)

According to the data presented in Table 5, the Kolmogorov–Smirnov test showed a significance value of 0.094 for the experimental group and 0.200 for the control group. Since both values were greater than 0.05, it can be concluded that the data in both groups were normally distributed. Therefore, a comparative analysis using an independent sample t-test could be conducted.

The independent sample t-test was used to test the hypothesis, following these criteria: if Sig. (2-tailed) > 0.05, H0 is accepted and Ha is rejected; if Sig. (2-tailed) < 0.05, H0 is rejected, and Ha is accepted. The descriptive statistics for both groups are presented in Table 6.

Table 6. Group Statistics Results

	Groups	N	Mean	Std. Deviation	Std. Error Mean
Disaster Preparedness	Experimental	96	87,029	7,5274	,7683
	Control	96	73,582	8,9855	,9171

(Source: Data Analysis, 2025)

From the information indicated in Table 6, both groups consisted of 96 students. The mean preparedness score for the experimental group was 87.02, while the control group achieved a mean score of 73.58. These results indicate that the experimental group demonstrated higher disaster preparedness than the control group. To determine whether the difference was statistically significant, the independent samples test results were analyzed and are presented in Table 7.

Table 7. Independent Samples Test Results

			Disaster Preparedness	
			Equal Variances Assumed	Equal Variances not Assumed
Levene's Test for Equality of Variances		F	4,602	
		Sig.	,033	
t-test for Equality of Means		t	11,240	11,240
		df	190	184,339
		Sig. (2-tailed)	,000	,000
		Mean Difference	13,4469	13,4469
		Std. Error Difference	1,1964	1,1964
	95% Confidence Interval of the Difference	Lower	11,0870	11,0866
		Upper	15,8067	15,8072

(Source: Data Analysis, 2025)

As indicated in Table 7, the Levene's Test for Equality of Variances showed a significance value of 0.033 < 0.05, indicating that the data variance between both groups was not homogeneous. Thus, interpretation was based on the assumption of equal variances. The Sig. (2-tailed) value was 0.000 < 0.05, meaning that H0 was rejected and Ha was accepted. Therefore, there was a statistically significant difference between the experimental and control groups regarding disaster preparedness. These results indicate that students taught using the simulation learning model integrated with local wisdom-based disaster education demonstrated significantly higher preparedness in facing the eruption of Gamalama Volcano compared with students who received conventional learning.

These findings align with earlier research demonstrating that simulation learning models effectively improve students' disaster preparedness competencies (Putri et al., 2024; Idrus et al., 2019). Similarly, prior work has established that local wisdom-based disaster education in schools enhances student preparedness for natural disasters (Sahudra et al., 2025; Astuti & Anandita, 2025; Masruroh et al., 2023; Suarmika et al., 2022; Juhadi et al., 2021; Mustofa & Handini, 2020). The present study thus confirms that the simulation learning model integrated with Ternate's local wisdom-based disaster education significantly improves student preparedness competencies in schools located within Mount Gamalama's volcanic hazard zone.

The simulation learning model integrated with local wisdom-based disaster education has proven effective not only in the specific context of Ternate's small volcanic island but also holds strong potential for replication across other small islands characterized by comparable disaster vulnerability profiles. The model's flexibility and adaptability allow it to be tailored to the social, cultural, and geographic conditions of different localities. In any replication effort, it is the integrative approach, rather than the specific content of Ternate's local wisdom, that is to be adopted: namely, the practice of grounding disaster content in the values and practices of the local community. With appropriate adjustments to simulation scenarios and the selection of contextually relevant local wisdom, this model offers a viable pathway for broad and sustainable implementation as a contextual disaster education strategy aimed at strengthening student preparedness across Indonesia's other small volcanic islands.

While the study yielded significant results, the findings warrant interpretation in light of certain methodological constraints. A primary limitation inherent in quasi-experimental designs is the possibility that uncontrolled extraneous variables may have influenced outcomes, including students' prior disaster-related experiences, family and community support structures, and exposure to disaster information through media or extra-school programs. These factors potentially affected student preparedness levels independently of the instructional treatment delivered.

CONCLUSION

The findings of this study demonstrated that the simulation learning model integrated with local wisdom-based disaster education was effective in improving the disaster preparedness of students living on the small volcanic island of Ternate. Students in the experimental group who received the integrated simulation-based learning achieved a preparedness index categorized as "very ready" (87.02), while the control group that received conventional learning reached the "ready" category (73.58). The comparative test results also showed a significant effectiveness difference between the two groups. Thus, it can be concluded that the simulation learning model integrated with local wisdom-based disaster education is an effective and applicable instructional approach for improving disaster preparedness among students in schools located in volcanic hazard areas. This model exhibits superiority over traditional learning methodologies due to its ability to link theoretical knowledge with practical applications while incorporating local wisdom as a relevant source of information. Therefore, this learning model can serve as a strategic alternative for disaster education in schools, especially those located in areas prone to Gamalama volcanic eruptions.

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