



The Effectiveness of Tornado Disaster Mitigation Education in Improving the Knowledge of Junior High School Students

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ABSTRACT

Schools in Indonesia face the challenge of low student knowledge and preparedness for tornado mitigation, a common hydrometeorological disaster that can threaten safety due to a lack of systematic disaster education. This study aims to determine the effectiveness of natural disaster mitigation education on tornadoes for ninth-grade students at SMPN 2 Pancur Batu. This study used a quantitative method with a one-group pretest-posttest pre-experimental design. The population in this study was all ninth-grade students at SMPN 2 Pancur Batu. The intervention involved 57 students in December 2025, with interactive counseling using visual media, discussions, and a three-point Likert scale pretest and posttest questionnaire to measure students' knowledge improvement. The results showed a significant increase in knowledge, with an average pretest score of 31.60 (SD=4.088) increasing to a posttest score of 32.65 (SD=4.104). Statistical test results showed a significant difference between the pretest and posttest scores ($t=-3.711$, $df=56$, $p=0.001$), indicating that the education provided had a real effect on increasing students' knowledge. The effect size (Cohen's $d = 0.492$) indicates that the effect of the education was moderate, meaning that this intervention was quite effective in increasing students' knowledge in building awareness of natural disasters for reducing more dangerous risks after a disaster.

Keywords: Disaster, Mitigation, Tornado.

ABSTRAK

Sekolah-sekolah di Indonesia menghadapi tantangan rendahnya pengetahuan dan kesiapsiagaan siswa terhadap mitigasi bencana angin puting beliung, bencana hidrometeorologi umum yang dapat mengancam keselamatan akibat kurangnya edukasi kebencanaan sistematis. Penelitian ini bertujuan untuk mengetahui efektivitas edukasi mitigasi bencana alam angin puting beliung terhadap siswa kelas IX SMPN 2 Pancur Batu. Penelitian ini menggunakan metode kuantitatif dengan desain pra-eksperimental one group pretest-posttest. Populasi dalam penelitian ini adalah seluruh siswa kelas IX SMPN 2 Pancur Batu. Intervensi melibatkan 57 siswa, pada bulan Desember 2025, dengan penyuluhan interaktif menggunakan media visual, diskusi, pretest dan posttest kuesioner skala Likert tiga poin yang mengukur peningkatan pengetahuan siswa. Hasil menunjukkan, peningkatan pengetahuan signifikan, dengan rata-rata skor pretest 31,60 (SD=4,088) naik menjadi posttest 32,65 (SD=4,104). Hasil uji statistik menunjukkan adanya perbedaan, yang signifikan antara nilai pretest dan posttest ($t=-3,711$, $df=56$, $p=0,001$), yang menandakan bahwa edukasi yang diberikan memberikan pengaruh nyata terhadap peningkatan pengetahuan siswa. Nilai ukuran efek (Cohen's $d = 0,492$) menunjukkan bahwa pengaruh, edukasi berada pada kategori sedang, sehingga intervensi ini cukup efektif dalam meningkatkan pengetahuan siswa dalam membangun kesadaran terhadap bencana alam untuk pengurangan risiko yang lebih berbahaya setelah pasca bencana. Oleh karena itu, edukasi kebencanaan disarankan untuk dilaksanakan secara berkelanjutan sebagai upaya pengurangan risiko bencana di lingkungan sekolah.

Kata Kunci: Bencana, Mitigasi, Angin Puting Beliung.

INTRODUCTION

Disasters are defined as events or a series of events that disrupt and threaten human life and livelihoods, whether caused by natural processes or human activities (Kurniawati, 2020; Danil, 2021). Beyond physical destruction and loss of life, disasters often result in long-term socioeconomic losses and psychological impacts on affected communities. Inadequate preparedness, particularly in areas with high population density and economic value, can significantly amplify disaster-related losses (Rijanta, Hizbaron, & Baiquni, 2018; Nurhasna, et al., 2025). Consequently, disaster risk reduction (DRR) has become a critical component of sustainable development and community resilience strategies worldwide.

Indonesia is among the countries with the highest vulnerability to hydrometeorological disasters, including tornado-like wind events locally known as tornado. National disaster records indicate that hydrometeorological hazards dominate disaster occurrences in Indonesia and exhibit an increasing trend over time (Amri et al., 2016). Tornado events are primarily triggered by atmospheric instability characterized by the formation of cumulonimbus clouds and extreme pressure gradients (Aeni & Anwar, 2024). Although these events typically occur over short durations, with an average lifespan of approximately 12 minutes, they can generate extensive physical damage and pose serious threats to human safety. Within the DRR framework, community preparedness is widely recognized as a key factor in minimizing disaster impacts (Badan Nasional Penanggulangan Bencana Indonesia, 2020).

Empirical evidence demonstrates that tornado events also affect densely populated urban areas. A notable case occurred in Jakarta on 22 November 2018, resulting in damage to public infrastructure, fallen trees, and widespread disruption of daily activities. By November 2018, a total of 77 tornado incidents had been recorded nationwide, causing damage to 1,801 buildings (Rusmala et al., 2021). These data underscore that tornado-related wind hazards represent a significant and recurrent meteorological threat across diverse settings, including residential zones and public institutions such as schools.

School-based disaster education has been increasingly recognized as an effective approach to enhancing disaster awareness, knowledge, and preparedness among children and adolescents, who are considered highly vulnerable groups during disaster events. Previous studies consistently report that disaster education programs significantly improve students' knowledge, attitudes, and preparedness levels (Widjanarko, & Minnafiah, 2018). In addition, mitigation is regarded as a cost-effective phase of disaster management compared to emergency response, rehabilitation, and reconstruction (Naibaho, Silaban, & Hutagalung, 2024). Indonesian Disaster Management Law No. 24/2007 emphasizes that mitigation efforts encompass both structural measures and the enhancement of public awareness and capacity (Pemerintah Pusat Indonesia, 2007). Nevertheless, existing school-based disaster education research remains disproportionately focused on earthquakes and floods, while hydrometeorological hazards despite their higher frequency in Indonesia receive comparatively limited scholarly attention (Badan Nasional Penanggulangan Bencana Indonesia, 2020).

A critical research gap therefore exists regarding the effectiveness of science- and technology-based disaster mitigation education specifically addressing tornado hazards at the junior high school level. Most existing programs remain generic and procedural, often emphasizing memorization of response steps without fostering a scientific understanding of atmospheric processes, early warning signs, and the rationale underlying mitigation actions (Sari, & Sudarti, 2025). The novelty of this study lies in the development and evaluation of an interactive, science and technology-based tornado disaster mitigation education program that integrates atmospheric science concepts with practical preparedness strategies (Sakurai & Shaw, 2022; Naibaho, Silaban, & Hutagalung, 2024). This approach is implemented in SMP Negeri 2 Pancur Batu, a school located in an area characterized by dynamic weather conditions, where preliminary observations indicate limited student knowledge and preparedness related to tornado hazards (Dwi, 2024; Alqulby et al., 2025).

Based on these considerations, the objective of this study is to examine the effectiveness of science- and technology-based tornado disaster mitigation education in improving the disaster-related knowledge of ninth-grade students at SMP Negeri 2 Pancur Batu. Specifically, this study aims to assess changes in students' knowledge levels before and after the implementation of an

interactive disaster education intervention, thereby contributing empirical evidence to school-based disaster risk reduction strategies for hydrometeorological hazards.

RESEARCH METHODS

This study employed a quantitative approach using a pre-experimental one-group pretest–posttest design. This design involved a single group of participants without a control group, with measurements conducted at two time points: before (pretest) and after (posttest) the intervention in the form of tornado disaster mitigation education. The design was selected to assess changes in students’ knowledge following the educational intervention (Sugiyono, 2019). A purposive sampling technique was applied, whereby participants were selected based on predefined characteristics relevant to the study objectives.

The study was conducted at SMP Negeri 2 Pancur Batu, Deli Serdang Regency, Indonesia. The site was chosen due to its geographical conditions and regional characteristics that indicate potential exposure to hydrometeorological hazards, particularly tornado-like wind events. The research activities were carried out in December 2025 as part of a structured program consisting of preparation, implementation, and evaluation phases. The study participants comprised 57 ninth-grade students. This age group was selected because adolescents are considered capable of understanding disaster mitigation concepts and are expected to act as information disseminators within their school and family environments.

Ethical approval for the study was obtained from the relevant institution through an official authorization letter (No. 400.3.12.1/685/KO/2025) issued by the UPT Formal Education Unit of SMP Negeri 2 Pancur Batu, Deli Serdang Regency. Prior to data collection, all participants received a comprehensive explanation regarding the study objectives, procedures, and potential benefits of the research entitled “Tornado Disaster Mitigation.” Participation was entirely voluntary, and all respondents provided informed consent without any form of coercion.

The implementation of the study began with a preparation phase, which included coordination with school authorities to determine the schedule, implementation procedures, and provision of supporting facilities. During this phase, educational materials on tornado disaster mitigation were developed and tailored to the characteristics of the participants and the school context. Before the delivery of the educational intervention, participants completed a pretest to assess their baseline knowledge of tornado hazards and mitigation measures.

Students’ levels of knowledge, preparedness, and attitudes were measured using a closed-ended questionnaire based on a three-point Likert scale (1 = disagree, 2 = agree, and 3 = strongly agree). The questionnaire consisted of 15 items covering knowledge of tornado disasters, early warning signs, and mitigation actions to be undertaken before, during, and after a disaster. Total scores were calculated by summing all item responses, with higher scores indicating better levels of knowledge and preparedness.

Data collection was conducted twice, namely before the intervention (pretest) and after the educational program (posttest). The collected data were analyzed quantitatively using a parametric statistical test, specifically the paired sample t-test, after confirming the assumption of normality. This analysis was performed to determine differences in scores before and after the intervention and to evaluate the effectiveness of the tornado disaster mitigation education program.

RESULTS

The results of the tornado disaster mitigation education program among ninth-grade students of SMP Negeri 2 Pancur Batu are presented below. Program effectiveness was evaluated by measuring students’ knowledge levels using the same questionnaire administered before (pre-test) and after (post-test) the educational intervention. A total of 57 students completed both assessments and were included in the analysis.

Table 1. Pre-test and Post-test Knowledge Scores of Students.

Variable	N	Mean	Standard Deviation	Standard Error
Pre-test	57	31.60	4.088	0.541
Post-test	57	32.65	4.104	0.544

Table 1 presents the descriptive statistics of students' knowledge scores before and after the educational intervention. The mean pre-test score was 31.60 (SD = 4.088), while the mean post-test score increased to 32.65 (SD = 4.104). This increase in the mean score indicates a positive change in students' knowledge levels following participation in the tornado disaster mitigation education program.

Prior to hypothesis testing, data normality was assessed to determine the appropriate statistical test. The Shapiro–Wilk normality test indicated that both pre-test and post-test scores were normally distributed, with p -values greater than 0.05. Given that the normality assumption was met and the sample size exceeded 30 participants, a paired sample t -test was applied to examine differences between pre-test and post-test scores.

Table 2. Results of the Paired Sample t -Test.

Paired Variables	Mean Difference	Standard Deviation	Standard Error	95% CI Lower–Upper)	t	df	p (2-tailed)
Pre-test – Post-test	-1.053	2.142	0.284	-1.621 to -0.484	-3.711	56	< 0.001

As shown in Table 2, the paired sample t -test yielded a t -value of -3.711 with 56 degrees of freedom ($df = 56$) and a two-tailed significance value of $p < 0.001$. This result indicates a statistically significant difference between pre-test and post-test scores. Therefore, the tornado disaster mitigation education program was statistically proven to significantly improve students' knowledge levels.

DISCUSSION

The findings of this study demonstrate an increase in students' knowledge scores following the implementation of tornado disaster mitigation education. The statistically significant difference between pre-test and post-test scores indicates that the educational intervention was associated with an improvement in students' knowledge levels. This result suggests that structured disaster education can play an important role in enhancing students' understanding of hydrometeorological hazards.

The observed improvement in knowledge is consistent with cognitive learning theory, which posits that information delivered in a structured, visual, and contextualized manner facilitates more effective encoding and retention of knowledge among learners. Interactive disaster education enables students to connect newly acquired information with their everyday experiences, thereby promoting deeper and more meaningful learning. This finding is supported by Sari et al. (2025), who reported that school-based disaster mitigation education significantly improves students' knowledge because schools provide a systematic and continuous learning environment.

Nevertheless, given that this study employed a pre-experimental design without a control group, the results cannot be interpreted as strong causal evidence. The observed increase in knowledge may also have been influenced by other factors, such as repeated exposure to the questionnaire (testing effect), students' motivation during the educational activities, or the learning environment at the time of implementation. These methodological considerations should be taken into account when interpreting the findings.

The results of this study are in line with previous research by Syamila et al. (2023) and Lestari et al. (2021), both of which reported that school-based disaster education interventions effectively improve students' knowledge and preparedness. The consistency of these findings reinforces the notion that schools represent a relevant and strategic setting for the implementation of disaster mitigation education, particularly for vulnerable age groups such as adolescents.

The use of visual media and interactive discussions in the present study likely contributed to the effectiveness of the educational intervention. Visual materials help simplify complex scientific concepts, such as the formation of cumulonimbus clouds and the atmospheric mechanisms underlying tornado events. This aligns with the findings of Anwar et al. (2023), who demonstrated that visual media in disaster education significantly enhance students' conceptual understanding and memory compared to conventional lecture-based methods.

The increase in post-test scores also suggests an improvement in students' understanding of early warning signs and basic mitigation actions related to tornado hazards. However, this study did not directly assess whether the observed increase in knowledge translated into actual behavioral changes during emergency situations, as no field observations or disaster simulations were conducted. According to Shaw et al. (2004), knowledge improvement represents an essential initial stage in the development of disaster preparedness, preceding the formation of risk perception, attitudes, and practical response behaviors, which typically evolve through a gradual and sequential process.

Compared with previous studies, this research adds empirical evidence within the context of hydrometeorological hazards, particularly tornado-like wind events, which have received relatively limited attention in school-based disaster education research. Thus, this study contributes to broadening the scope of disaster education beyond commonly examined hazards such as earthquakes and floods.

This study has several limitations that should be acknowledged. First, the use of a pre-experimental design without a control group limits the ability to draw causal conclusions. Second, the sample size was relatively small and drawn from a single school, which restricts the generalizability of the findings. Third, data collection was conducted over a short time frame, preventing the assessment of long-term knowledge retention. Fourth, knowledge and attitudes were measured using self-reported questionnaires, which may be subject to respondent bias.

Despite these limitations, the improvement in students' knowledge remains an important prerequisite for the development of disaster preparedness. Adequate disaster literacy influences individuals' attitudes and decision-making processes during emergency situations. Students with higher levels of disaster knowledge are more likely to respond promptly to early warning information and to take appropriate self-protective actions (Sari et al., 2025).

Accordingly, future research is recommended to employ quasi-experimental or experimental designs, involve a larger number of schools, and incorporate simulation-based evaluation methods to assess changes in disaster preparedness behaviors more comprehensively.

CONCLUSION

The tornado disaster mitigation education provided to ninth-grade students of SMP Negeri 2 Pancur Batu resulted in an improvement in students' knowledge levels. This was evidenced by a statistically significant difference between pre-test and post-test scores following the implementation of a science- and technology-based educational intervention. The effect size, which fell within the moderate range, indicates that the educational program had a meaningful practical impact. Although behavioral changes could not be comprehensively assessed, the observed increase in students' understanding and awareness represents an important foundation for the development of disaster preparedness. Therefore, disaster education should be implemented in a continuous and integrated manner within school settings as an early disaster risk reduction strategy.

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