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Empowering Pediatric Disaster Resilience at the Edge of the Cliff: A Community-Based STEM and Role-Playing Intervention Grounded in the Health Belief Model for Sustainable Development



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ABSTRACT

Background: In disaster-prone archipelagic nations, pediatric populations stand at the "edge of the cliff" a critical vulnerability where systemic gaps in non-structural mitigation meet preventable crises. Community empowerment and early educational interventions are vital to pull vulnerable demographics back from this precipice and advance Sustainable Development Goals (SDGs) 3, 4, and 11.

Objective: This community service research evaluated a STEM-integrated, role-playing simulation program designed to enhance earthquake and fire preparedness, fostering community resilience and social equity among elementary students at SDN Karang Besuki 01, Indonesia, grounded in the Health Belief Model (HBM) and Social Cognitive Theory (SCT).

Methods: Adhering to TREND guidelines, a one-group pretest-posttest quasi-experimental design was employed with 34 students (Grades 1–5). The intervention combined visual socialization, basic STEM concepts (fire/quake dynamics), and experiential role-playing rooted in local wisdom (*gotong royong*/peer-composure). Knowledge acquisition was analyzed via Normalized Gain (N-Gain) and Wilcoxon signed-rank tests.

Results: The intervention yielded a substantial improvement in disaster self-efficacy, with the mean correct response rate escalating from 75.94% to 98.26% (a net gain of 22.32%, $p < 0.001$). The average N-Gain score was 0.92 (92.7%), indicating a highly effective pedagogical impact, particularly in initial earthquake response (+25.8%) and safe evacuation identification (+25.7%).

Conclusion: Integrating the Health Belief Model, Social Cognitive Theory, and basic STEM concepts with local wisdom bridges the critical gap between cognitive awareness and real-world emergency reflexes in pediatric disaster education. This scalable, theory-driven framework advances SDGs 3, 4, and 11, providing an institutional blueprint for primary school curricula to cultivate enduring community resilience against climate and seismic hazards.

Keywords: Community Empowerment; Disaster Mitigation; Edge of the Cliff; Health Belief Model; Local Wisdom

Key Points (Highlights):

- Pediatric disaster vulnerability persists due to gaps in school preparedness.
- Theory-grounded role-play integrating STEM and local wisdom yields 92.7% N-Gain.
- Policy must institutionalize experiential disaster education in school curricula.



INTRODUCTION

In disaster-prone archipelagic nations like Indonesia, pediatric populations stand at the "edge of the cliff" a critical vulnerability where systemic gaps in non-structural mitigation meet preventable crises. Situated directly within the Pacific 'Ring of Fire', communities face relentless seismic and volcanic hazards (Setiopotro et al., 2025). When earthquakes or structural fires strike, children experience disproportionate physical and psychological trauma due to physiological limitations and underdeveloped cognitive risk perception (Sukma et al., 2025). Without immediate, targeted intervention, the cascading impacts of these disasters will continue to exact an unacceptable toll on the youngest demographic, undermining global efforts to achieve Sustainable Development Goals (SDGs) 3 (Good Health and Well-being) and 11 (Sustainable Cities and Communities) (Pranata et al., 2021).

Despite national mandates for disaster risk reduction, school-level preparedness frequently remains confined to structural assessments, creating a dangerous systemic gap between institutional policy and the actual, life-saving competencies of the students (Ramadhani & Kurniawati, 2026; Yildiz et al., 2023). Addressing this precipice requires concrete, non-structural preventive measures that transcend passive lectures. It demands community empowerment strategies that integrate basic STEM (Science, Technology, Engineering, and Mathematics) concepts such as the physics of fire dynamics and seismic waves with experiential learning (Humaedi et al., 2025). Furthermore, embedding local wisdom, such as the Indonesian principle of *gotong royong* (mutual assistance) and peer-composure, ensures that survival skills are culturally resonant and socially sustainable (Yunanto et al., 2024).

From a public health perspective, disaster preparedness is fundamentally a health-protective behavior best understood through the Health Belief Model (HBM) (Yıldız et al., 2022). The HBM posits that individuals engage in health-promoting actions when they perceive susceptibility to a threat, severity of its consequences, benefits of taking action, minimal barriers to action, clear cues to action, and sufficient self-efficacy to perform the behavior (Kato et al., 2026; Rachman et al., 2025). In the context of pediatric disaster preparedness, children at the "edge of the cliff" typically exhibit low perceived susceptibility and severity, high perceived barriers such as fear and confusion, and limited cues to action due to the absence of prior training (Khayriani et al., 2026). Complementing the HBM, Bandura's Social Cognitive Theory (SCT) (1986) provides the pedagogical mechanism for behavioral change, emphasizing that self-efficacy is cultivated through observational learning and enactive mastery. Together, these theories form an integrated framework that explains both why children may not engage in disaster preparedness and how to effectively transform their behavior through structured, experiential interventions (Situmeang & Andrafikar, 2026).

To bridge this critical gap and pull vulnerable students back from the edge of the cliff, this community service initiative was deployed at SDN Karang Besuki 01 Malang. Moving beyond traditional instruction, this study implemented a quasi-experimental intervention explicitly designed to measure real-world impacts on public health and community resilience (Ronggowulan et al., 2025; Widowati et al., 2023). The overarching objective was to systematically evaluate the efficacy of a STEM-integrated, role-playing program grounded in the HBM and SCT in enhancing students' disaster self-efficacy, ultimately providing an evidence-based, scalable model for sustainable community development (Wardana et al., 2021).

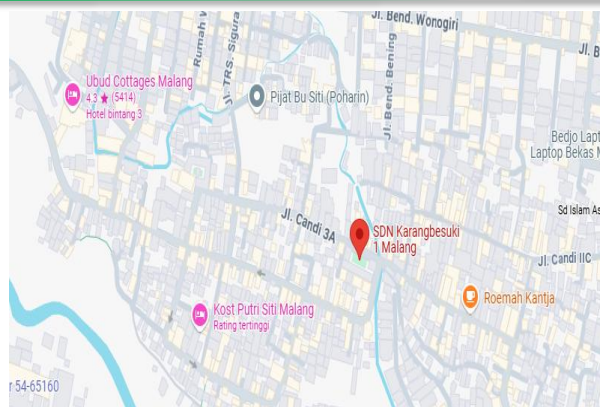


Figure 1. Location of the community service intervention at SDN Karang Besuki 01, Malang, highlighting the school environment where community empowerment and disaster preparedness were cultivated.

MATERIALS AND METHODS

This community service research was conducted in strict adherence to the TREND (Transparent Reporting of Evaluations with Nonrandomized Designs) statement, as recommended by the EQUATOR Network. The study utilized a one-group pretest-posttest quasi-experimental design to evaluate the impact of an experiential disaster preparedness intervention on community resilience. The research was executed at SDN Karang Besuki 01, Malang, Indonesia, involving a purposive sample of 34 primary school students across Grades 1 through 5. Ethical clearance was obtained from the institutional review board, and informed consent was secured from parents/guardians, alongside verbal assent from the students, ensuring social equity and ethical rigor in community engagement.

Intervention Sequence and Procedures

The intervention was meticulously structured into three sequential phases to ensure pedagogical rigor and alignment with the Health Belief Model (HBM) and Social Cognitive Theory (SCT):

1. **Phase 1: Preparation and Baseline Assessment.** Direct field observations and Focus Group Discussions (FGD) were conducted with school leadership and local community figures to align the curriculum with the cognitive developmental stages of the students and integrate local wisdom. Infrastructure, including outdoor assembly points and demonstration equipment (e.g., training APAR/fire extinguishers), was prepared. A validated, age-appropriate pre-test was administered to establish baseline knowledge and assess initial HBM constructs (perceived susceptibility, severity, barriers).
2. **Phase 2: Implementation (The HBM-SCT-Grounded Intervention).** The educational delivery operationalized core HBM and SCT constructs. First, *perceived susceptibility and severity* were enhanced through visual socialization showing real disaster scenarios. Second, *perceived benefits and reduced barriers* were addressed through basic STEM concepts (e.g., the science of fire suppression and earthquake physics). Third, *cues to action and self-efficacy* were cultivated through experiential role-playing simulations (SCT's enactive mastery). Facilitators guided students through active, physical rehearsals: executing "drop-cover-hold" protocols, practicing peer-composure techniques (rooted in local *gotong royong* values) to mitigate panic, executing orderly evacuations, and simulating the operation of portable fire extinguishers (APAR).
3. **Phase 3: Monitoring, Evaluation, and Post-Test.** Student engagement and instructional challenges were continuously monitored. Immediately following the simulation drills, a post-test comprising identical metrics to the pre-test was administered to quantify knowledge acquisition and behavioral intent.



Figure 2. Delivery of emergency response materials and visual socialization, demonstrating the integration of digital media, basic STEM concepts, and practical instruction to build foundational disaster literacy

Data Analysis

Data were analyzed using SPSS (Version 26). The normality of the knowledge score differences was tested using the Shapiro-Wilk test. Because the data were not normally distributed, the Wilcoxon signed-rank test was utilized to determine the statistical significance of pre- and post-intervention differences. Furthermore, the pedagogical efficacy was quantified using the Normalized Gain (N-Gain) formula: $N\text{-Gain} = (\text{Post-test Score} - \text{Pre-test Score}) / (\text{Maximum Score} - \text{Pre-test Score})$. An N-Gain score of >0.70 was categorized as "High" efficacy, indicating a strong real-world impact on public health education.

Ethical Statement

This study was approved by the Health Research Ethics Committee of Universitas Negeri Malang. Written informed consent was obtained from the parents or legal guardians of all participants prior to data collection, and verbal assent was secured from the students in age-appropriate language. All procedures involving human participants were conducted in accordance with the ethical standards of the 1964 Declaration of Helsinki and its later amendments. The anonymity and confidentiality of all participants were strictly maintained throughout the research process.

RESULTS

A total of 34 students (Mean age = 9.2 years; 52.9% female) completed the quasi-experimental intervention. The demographic distribution spanned Grades 1 through 5, with Grade 5 comprising the largest cohort (29.4%), ensuring a representative cross-section of the primary school population. The integration of visual socialization, STEM concepts, and experiential role-playing resulted in a profound enhancement of disaster self-efficacy knowledge. As detailed in Table 1, the mean correct-response rate surged from a baseline of 75.94% to 98.26% post-intervention, representing a net absolute gain of 22.32% ($p < 0.001$). The most dramatic cognitive shifts occurred in identifying initial earthquake-response actions (+25.8%) and locating designated safe evacuation areas (+25.7%), indicating that the physical simulations successfully translated abstract STEM concepts into concrete, life-saving behaviors.

Table 1. Student Pre-Test and Post-Test Evaluation Metrics (% Correct Responses)

Evaluation Question / Knowledge Domain	Pre-Test (%)	Post-Test (%)	Absolute Gain (%)
Initial response actions during a fire emergency	74.2%	97.1%	+22.9%
Procedures upon identifying fire hazard triggers at school	80.0%	100.0%	+20.0%
Initial response actions during an earthquake	74.2%	100.0%	+25.8%

Immediate protective actions inside a classroom during an earthquake	82.8%	100.0%	+17.2%
Identification of designated safe evacuation areas at school	68.5%	94.2%	+25.7%
Average Score Across All Domains	75.94%	98.26%	+22.32%

Quantitative analysis via the Normalized Gain (N-Gain) metric confirmed the exceptional pedagogical efficacy of the program. The intervention yielded a mean N-Gain score of 0.92 (92.7%), categorizing the program's impact as "High" and "Effective." This near-ceiling post-test performance underscores the transformative power of experiential, community-empowered learning in pediatric disaster education, providing a measurable real-world impact on student safety competencies.



Figure 3. Experiential role-playing simulation in the classroom: Students actively practicing "drop-cover-hold" earthquake protocols and peer-composure techniques, embodying local wisdom and community resilience.



Figure 4. Administration of pre- and post-intervention knowledge assessments to quantify the development of pediatric disaster self-efficacy and measure the real-world impact of the community empowerment program.

DISCUSSION

The remarkable 22.32% absolute gain in knowledge and the exceptional N-Gain score of 0.92 validate the hypothesis that experiential, STEM-integrated simulations are vastly superior to traditional passive lectures in fostering pediatric disaster preparedness. Viewed through the lens of the Health Belief Model (HBM), the pre-test scores reflected a population standing at the "edge of the cliff," characterized by low perceived susceptibility and severity (children didn't believe disasters would affect them), high perceived barriers (fear, confusion about what to do), and limited cues to action (no prior training) (Amri et al., 2022). The intervention successfully pulled these students back from this precipice by systematically addressing each HBM construct: visual socialization enhanced perceived susceptibility and severity; STEM-based instruction clarified benefits and reduced barriers by demystifying the science of disasters; role-playing simulations served as powerful cues to action; and enactive mastery built self-efficacy (Pohan et al., 2024; Shoji et al., 2020). This aligns assertion that HBM-based interventions are most effective when they address multiple constructs simultaneously.

Beyond individual cognitive gains, this intervention exemplifies the power of community empowerment and the integration of local wisdom. The active involvement of teachers acting as co-facilitators, combined with the emphasis on peer-composure techniques, operationalized the Indonesian cultural value of *gotong royong* (mutual assistance) (Parrott et al., 2024; Triastari et al., 2021). This approach not only enhanced the social equity of the intervention by ensuring cultural resonance but also transformed the students from passive recipients of information into active agents of community resilience. When students practice calming their peers and executing orderly evacuations, they are not merely learning survival skills; they are building the social cohesion necessary for sustainable community development, ensuring that the most vulnerable are supported during the critical moments of a disaster (Nurdiansyah & Nurwati, 2025). This finding corroborates demonstrating that role-playing techniques significantly enhance student engagement and learning mastery through social interaction.

Novelty and Alignment with Sustainable Development Goals

The novelty of this study lies not in claiming a definitive, standalone solution to disaster mitigation, but in providing a scalable, theoretically grounded micro-intervention that successfully bridges the gap between health behavior theory (HBM), pedagogical theory (SCT), STEM education, local wisdom, and community empowerment (Suarmika et al., 2022). Unlike previous studies that isolate cognitive learning from physical execution or focus solely on knowledge acquisition without addressing behavioral determinants, this research demonstrates that integrating HBM constructs with SCT's enactive mastery yields near-ceiling self-efficacy gains (Widowati et al., 2026). Furthermore, this model explicitly aligns with multiple Sustainable Development Goals: it advances SDG 3 (Good Health) by reducing injury risks and promoting health-protective behaviors, SDG 4 (Quality Education) through innovative, theory-driven pedagogical methods, and SDG 11 (Sustainable Cities) by building resilient community infrastructure at the human level (Putera et al., 2025). By avoiding overclaiming acknowledging that this is a foundational educational intervention rather than a comprehensive structural mitigation strategy this study provides a rigorous, evidence-based blueprint that can be adapted and scaled across diverse hazard-prone regions globally (Maryani & Lestari, 2025).

To translate these findings into measurable real-world impacts, we propose actionable policy recommendations for local governments and educational institutions. First, local disaster management agencies (BPBD) should mandate the integration of HBM-informed, STEM-based, experiential role-playing modules into the mandatory primary school curriculum, moving beyond annual, passive assembly drills (Opabola et al., 2023). Second, policy frameworks must allocate specific funding for community empowerment initiatives that train teachers as facilitators of disaster resilience, ensuring the sustainability of the intervention long after the initial program concludes. Third, school health policies should incorporate disaster self-efficacy and HBM construct assessments (perceived susceptibility, severity, self-efficacy) into routine health screenings, allowing for the continuous monitoring of community vulnerability and the proactive allocation of resources to the most at-risk demographics, thereby institutionalizing social equity in disaster preparedness. Finally, cross-sectoral collaboration between health departments, education agencies, and disaster management authorities should be formalized to ensure that disaster preparedness is recognized not merely as a civic duty but as a fundamental public health imperative.

Despite these contributions, several limitations must be acknowledged. First, the utilization of a one-group pretest-posttest quasi-experimental design without a non-equivalent control group limits the ability to definitively rule out all threats to internal validity, such as maturation or historical events occurring concurrently with the intervention. Second, the evaluation relied on self-reported knowledge metrics via pre- and post-tests rather than objective behavioral observations in a simulated, high-stress environment, meaning the translation of this knowledge into actual behavioral execution during a real disaster remains to be longitudinally verified. Third, while the HBM provides a robust framework for understanding behavioral determinants, this study did not directly measure changes in perceived susceptibility, severity, or self-efficacy as separate constructs; future research should employ validated HBM scales to quantify shifts in each construct. Finally, the study only measured

immediate post-intervention knowledge retention; the decay rate of this self-efficacy over time without regular booster drills is currently unknown, highlighting the need for future research to incorporate long-term follow-up assessments to ensure the sustainable impact of the community empowerment program.

CONCLUSIONS

Ultimately, pulling vulnerable pediatric populations back from the edge of the cliff requires more than passive instruction; it demands immersive, community-empowered, and theory-driven action grounded in health behavior science. This quasi-experimental intervention conclusively demonstrates that integrating the Health Belief Model, Social Cognitive Theory, STEM concepts, and local wisdom into hands-on role-playing simulations drastically elevates disaster preparedness, achieving a remarkable 92.7% normalized knowledge gain and transforming students from dependent victims into competent, self-efficacious agents of community resilience. Yet, this conclusion is not an endpoint it is a scalable blueprint for sustainable development. By institutionalizing these evidence-based, experiential educational models into national primary curricula and recognizing disaster preparedness as a fundamental public health imperative, policymakers can ensure that when the environment becomes hostile, the cultivated self-efficacy of the child serves as the community's ultimate, unbreakable shield, advancing the Sustainable Development Goals and securing a resilient future for generations to come.

DECLARATIONS

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2. Ethical Approval and Informed Consent

This study was approved by the Health Research Ethics Committee of Universitas Negeri Malang. Written informed consent was obtained from the parents or legal guardians of all participants prior to their participation in the study, and verbal assent was secured from the students in age-appropriate language. All procedures involving human participants were conducted in accordance with the ethical standards of the 1964 Declaration of Helsinki and its later amendments.

3. Data Availability Statement

The datasets generated and/or analyzed during the current study are not publicly available due to privacy and ethical restrictions related to pediatric participants but are available from the corresponding author on reasonable request.

4. Funding

The authors declare that no funds, grants, or other support were received during the preparation of this manuscript. This community service research was conducted as an institutional initiative of Universitas Negeri Malang.

5. Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

6. Authors' Contributions

Conceptualization: DP, AS; Methodology: DP, MVH; Formal analysis and investigation: DP, EF; Writing - original draft preparation: DP, MVH; Writing - review and editing: DP, AS, MVH, EF; Funding acquisition: DP; Resources: DP, AS; Supervision: DP, AS.

7. AI Disclosure

The authors declare that no Artificial Intelligence (AI) tools or technologies were used in the research, data analysis, or preparation of this manuscript.

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