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Bringing Earthquake Drills Home: A Virtual Reality-Based Simulation for Independent Earthquake Preparedness

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ABSTRACT

This study develops and evaluates a Virtual Reality (VR)-based earthquake preparedness simulation designed for independent home-based learning among lower secondary students. Responding to the need for more flexible, contextual, and student-centred disaster education in high-risk regions such as Bali, the simulation was created using a Human-Centered Design (HCD) framework to ensure simplicity, usability, and local relevance. A post-test-only quasi-experimental design was employed, comparing two groups: one using the VR simulation and the other using PowerPoint-based materials, both accessed autonomously from home. Students' earthquake preparedness knowledge was assessed using a validated 15-item multiple-choice instrument adapted from Johnson et al. (2014). As the data did not meet normality assumptions, a Mann-Whitney U test was used to analyse group differences. Results indicated a statistically significant advantage for the VR group, demonstrating higher levels of earthquake mitigation knowledge compared to the PPT group. Beyond effectiveness, the VR intervention offered greater learning flexibility, enabling students to revisit content repeatedly at their own pace. These findings suggest that VR-based autonomous learning holds strong potential for large-scale adoption in disaster-prone regions and may be further adapted for additional hazards and educational levels.

Keywords: Virtual Reality, independent learning, distance learning, disaster preparedness, earthquake mitigation.

INTRODUCTION

Indonesia ranks among the world's most disaster-prone nations, particularly in relation to geological hazards such as earthquakes (Achmad. 2025). Bali, situated along the active Sunda Arc, faces a persistent seismic threat, yet, disaster education within its formal education systems remains heavily dependent on lecture-based approaches or sporadic drills (Çoban & Göktaş, 2022; Faral et al., 2024 Widyati, 2024; Junaidi et al., 2025).

Emerging research suggests that disaster education must move beyond passive information delivery toward experiential and emotional resonant formats that foster both understanding and self-eficacy (Fu & Zhang, 2024; Ibrahim et al., 2025). In this regard, Virtual Reality (VR) has gained attention as a meaningful medium capable of simulating realistic risk scenarios in safe, controlled environments (Feng et al., 2020; Rajabi et al., 2022; Maragkou et al., 2023). However, most VR-based disaster education initiatives are conducted within laboratories or supervised classroom setting. Very few explore VR as a tool for independent, home-based learning despite the growing availability of low-cost headsetss or head-mounted displays (HMDs) and mobile integration (Hamad & Jia, 2022; Ahmadi et al., 2024)

This study addresses this gap by designing and evaluating a VR-based earthquake preparedness simulation intended for students as fully independent to to be used at home. By moving the learning experience outside the classroom, the intervention seeks to provide a more flexible, learner-driven model of disaster education, one that values not only cognitive acquisition but also emotional safety, contextual familiarity, and the autonomy of the learner.

Problem Statement

Disaster education in Indonesia remains largely constrained by institution-dependent delivery models that assume teacher presence, scheduled drills, or classroom access (Sukirman et al., 2019; Giacomin, 2014). Although VR offers a promising alternative, its current implementations rarely extend beyond guided demonstrations, leaving unanswered whether students can genuinely learn on their own using immersive technology.

There is limited empirical evidence on the effectiveness of VR when delivered as a self-directed, home-based learning medium via affordable head-mounted displays (HMDs). Without such validation, VR risks being regarded as an experimental novelty rather than a scalable educational solution. Schools and policymakers may hesitate to invest in immersive technologies unless it is proven that VR can outperform conventional formats such as PowerPoint-based self-study, especially in unsupervised contexts (Alshowair et al., 2024; Kaggwa et al., 2025).

Hence, this study seeks to (1) develop a contextually relevant VR-based earthquake preparedness simulation that can be accessed independently by lower secondary students at home, and (2) evaluate its effectiveness in enhancing earthquake mitigation knowledge when compared to traditional PowerPoint-based self-learning. By positioning VR as a stand-alone and scalable medium for disaster preparedness, this study establishes foundational evidence for its wider adoption across disaster-prone regions in Indonesia.

PRODUCT DESCRIPTION & METHODOLOGY

The learning intervention developed in this study is a Virtual Reality (VR)-based earthquake preparedness simulation specifically designed for independent use by lower secondary students within their home environments. The simulation provides a multimodal and sensory-rich experience, combining visual disturbances, ambient seismic sounds, and concise textual cues to guide appropriate mitigation responses. Engineered for self-directed engagement, the module requires no real-time facilitation. To enhance cultural and contextual relevance, the virtual environment was modelled after the spatial characteristics of typical Indonesian school settings, enabling students to navigate familiar locations and rehearse evacuation procedures in a recognisable context.

Figure 1. School layout in VR simulation

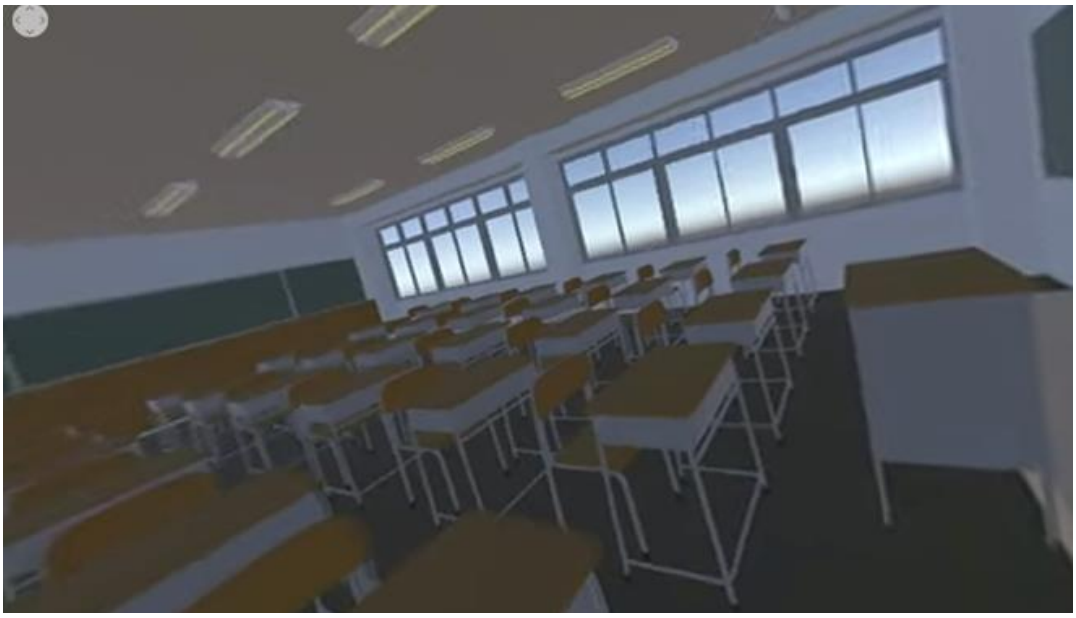
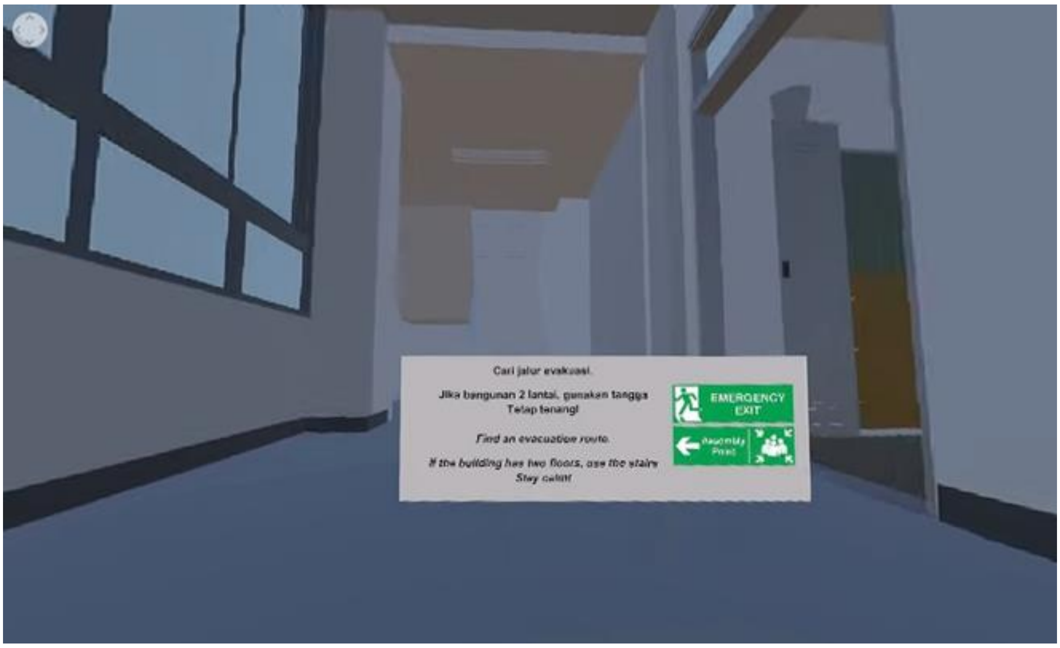


Figure 2. Brief textual instruction in VR



The product development process followed a Human-Centered Design (HCD) framework, progressing through several iterative stages: discover (analyzing user needs and context through literature review), define (determining design characteristics), design & prototype (initial product development), test (validation by content and learning media experts, as well as limited trials), and implement (student use at home). While the earlier stages of the HCD cycle were carried out in a previous, small-scale pilot study, this research emphasizes the implementation phase at a broader scale.

A quantitative post-test-only quasi-experimental design was employed. Participants were divided into two parallel groups: an experimental group (n = 114) that interacted with the VR simulation independently at home, and a control group (n = 114) that studied identical content through a PowerPoint (PPT) module, also under home-based self-study conditions. The intervention spanned one week, with students instructed to access the material at least once every two days. To ensure technological readiness, students in the VR group received a brief in-school onboarding session before home deployment.

Earthquake preparedness knowledge was assessed using a 15-item multiple-choice test adapted from Johnson et al. (2014), originally developed to evaluate learning outcomes following the ShakeOut drill initiative in the United States. All items demonstrated satisfactory validity (Pearson's $r > 0.26$, $p < 0.05$) and internal consistency (Cronbach's $\alpha = 0.726$). Preliminary analysis using the Shapiro–Wilk test indicated non-normal distribution ($p < 0.05$); therefore, the Mann-Whitney U test was selected as an appropriate non-parametric statistical method to compare post-test scores between groups.Based on the objectives and methods used, the following hypotheses were formulated:

Based on the objectives and methods used, the following hypotheses were formulated:

H_0: There is no significant difference in the level of earthquake mitigation knowledge between students who studied with VR simulations and students who studied with PPT materials independently at home.

H_1: There is a significant difference in the level of earthquake mitigation knowledge between students who studied with VR simulations and students who studied with PPT materials independently at home.

POTENTIAL FINDINGS AND COMMERCIALISATION

The analysis revealed a statistically significant difference between the experimental and control groups ($p < 0.001$), with students who used the VR simulation demonstrating substantially higher levels of knowledge regarding earthquake preparedness. This result highlights not only the cognitive impact of immersive learning but also the advantages of enabling students to engage with the material on their own terms, at their own pace, in familiar environments, and through repeated exposure. Such conditions may be particularly conducive to the internalisation of safety behaviours, as they allow learners to process risk-related information both intellectually and emotionally.

Table 1. Mean Ranks of Earthquake Mitigation Knowledge

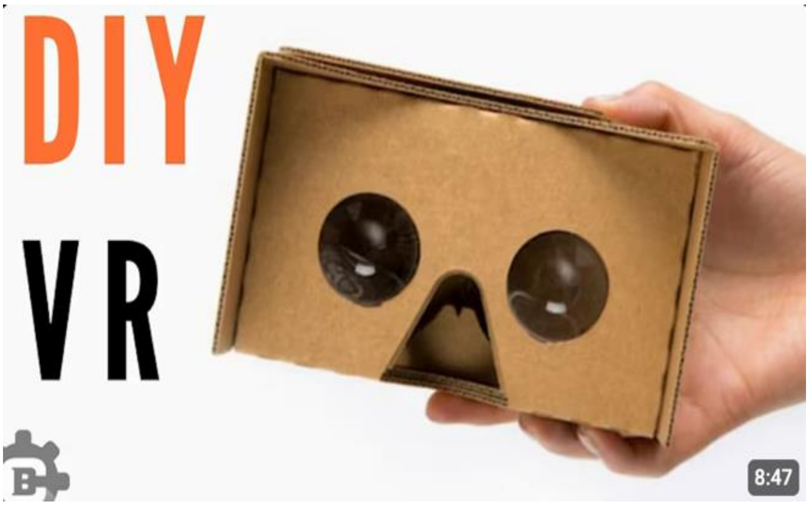
Group	N	Mean Rank
Control	114	72.68
Experiment	114	156.32
Total	228	

Table 2. Mann-Whitney U Test Summary

Statistics Test	Value
Mann-Whitney U	1730,000
Z	-9,647
p-value (2-tailed)	0,000

Beyond effectiveness, the home-based implementation of VR offers several practical advantages. It reduces dependency on school infrastructure, allows for asynchronous and self-paced learning, and expands access to disaster education in areas where conventional resources may be limited. Moreover, the use of low-cost cardboard headsets ensures that the technology remains accessible to a wide range of learners, including those in underserved or remote communities. Currently, numerous easy tutorials about making DIY Google Cardboard can be found online.

Figure 3. VR Cardboard DIY on Youtube (Creativity Buzz, 2016)



From a scalability perspective, the product is well-positioned for broader dissemination. Its simplicity, cultural adaptability, and minimal hardware demands make it suitable for integration into national or regional disaster education programmes. With institutional support from local governments, non-governmental organisations, or agencies such as the Indonesian National Disaster Management Authority (BNPB), the VR simulation could serve as a complementary tool alongside existing school-based initiatives.

Thus, the model offers strong potential for adaptation to other types of disasters, such as floods or fires, and for implementation at different educational levels. The underlying framework may also be expanded to include features such as formative assessment or integration with mobile learning platforms, further enhancing its relevance and impact.

NOVELTY AND RECOMMENDATIONS

The principal innovation of this study lies in its application of Virtual Reality not as a supplementary classroom tool, but as a fully autonomous, home-based learning medium for disaster preparedness. Whereas previous studies have typically implemented VR within controlled environments and under teacher supervision (Feng, González, Amor, et al., 2020; Feng, González, Mutch, et al., 2020; Sukirman et al., 2019), this project relocates the learning experience to the learner's own space. In doing so, it redefines disaster education as a self-directed process rather than an institution-bound exercise. Students are not positioned as passive recipients of instruction, but as active agents navigating realistic, risk-based scenarios in an environment that mirrors their lived reality.

This learner-centred reconfiguration introduces a dual novelty. First, it demonstrates that VR can operate effectively without facilitation, thereby supporting flexibility, repetition, and personal reflection qualities often absent in conventional disaster drills or classroom lectures. Second, the simulation was intentionally designed with inclusivity in mind: minimal text, intuitive interaction cues, and locally contextualised visual environments ensure accessibility across varying literacy levels and regional backgrounds. Rather than presenting preparedness as an abstract obligation, the experience situates it within familiar surroundings, strengthening emotional resonance and internalisation. Building on these insights, future development should move toward longer-term validation, examining whether knowledge gains persist over time and translate into behavioural readiness during simulated evacuation tasks. The framework also shows strong adaptability potential and could be expanded to cover other high-risk scenarios, such as floods, fires, or landslides, and trialled with learners at different educational stages, from primary to adult community groups. Subsequent versions may incorporate formative feedback, adaptive difficulty, or progress tracking through mobile analytics, enabling the system to support both learning and monitoring functions simultaneously. For broader impact, partnership with agencies such as BNPB, BPBD, or the Ministry of Education would be instrumental in formalising VR as a recognised disaster education supplement within national curricula, especially in regions where schooling is frequently disrupted. Accessibility can be further widened through the inclusion of audio narration, multilingual support, or haptic cues to accommodate learners with limited literacy or sensory impairments.

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