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EFFECT OF AUGMENTED REALITY-BASED EDUCATION ON DISASTER PREPAREDNESS AMONG RURAL COMMUNITIES IN DISASTER-PRONE AREA, INDONESIA: A PILOT STUDY

Nyayu Nina Putri Calisanie[1,2], Tukimin bin Sansuwito[1], Regidor III Dioso[3], Linlin Lindayani[2]

[1] Department of Nursing, Center of Postgraduate Studies, Lincoln University College Malaysia, Malaysia
[2] Department of Nursing, Sekolah Tinggi Ilmu Keperawatan PPNI Jawa Barat, Indonesia
[3] Department of Health Science, Lincoln University College Malaysia, Malaysia

Corresponding author: nyayuninaputricalisanie@gmail.com

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ABSTRACT

Background: Disaster preparedness initiatives primarily utilize three conventional training methods: classroom instruction, web-based training with pre-recorded material, and real-life drills and tabletop activities. Augmented reality offers a promising solution for enhancing disaster preparedness.

Objectives: This study aimed to determine the effect of augmented reality-based education on disaster preparedness among rural communities in disaster-prone area, Indonesia.

Methods: This study was This study employed a quasi-experimental with control group and repeated measure design. Data was collected between June to November 2023. Assessment of study outcome was done before intervention (T0), immediately after intervention (T1), and 2 weeks after the intervention (T2). The sample in this study was adult aged above 18 years old, able to write and read, without any cognitive of mental disorder, having at least 6 months of experience as a cadre, and having a smartphone. Sample was recruited using a convenience sampling. Household emergency preparedness scale was used to measure variable. The analysis used ANOVA repeated test and general estimation equation (GEE).

Results: In the intervention group there was significant improvement of disaster preparedness from 2.56 (SD=1.22) to 4.22 (SD=1.23) at T2 with a modest effect size of 0.42. While in control group, no significant improvement showed at T2 ($p>0.05$). The findings of the GEE analysis revealed a statistically significant interaction between time and group in relation to disaster preparedness ($ß = 11.3$ (95% CI=5.22 – 14.34, $p < 0.001$).

Discussion: Augmented reality-based education has potential effect on enhancing individual disaster preparedness in rural communities in disaster-prone area West Java, Indonesia. Future studies are needed to confirm this finding using more robust design and larger sample size.

Keywords: Augmented reality, education, disaster, preparedness, community

INTRODUCTION

Disasters are significant disruptions that exceed a community or society's ability to manage resources, causing substantial losses and impacts (WHO, 2019). The World Health Organization (WHO) reports that each year, over 190 million people are affected by natural disasters (MURRAY, 2020). Indonesia, situated in the Pacific Ring of Fire, is at risk of natural disasters such as earthquakes, tsunamis, and volcanic eruptions due to its significant tectonic activity (National Agency for Disaster Management, 2023). In 2022, Indonesia experienced 3,350 natural catastrophes, including extreme weather, landslides, fires,

earthquakes, and volcano eruptions, resulting in 5,143,027 fatalities and a total economic loss of 1,34 trillion Rupiah (National Agency for Disaster Management, 2023). Earthquakes are one of the major disasters that has caused the most harm throughout the world in the last few decades (Bhandari et al., 2023). Indonesia experienced seven earthquakes with a Richter scale of four to five on February 23, 2024, indicating a high frequency of earthquakes (BNPB, 2020). The global severity of disaster-related damages underscores the need for effective disaster risk management and government intervention (Bogati & Gautam, 2021).

Disaster preparedness is a proactive behavior that minimizes harm and property loss, enabling temporary disruptions from hazard activity (Espina & Teng-Calleja, 2020). Disaster preparedness encompasses community, institutional, family, and individual layers (Atreya et al., 2019; Han et al., 2019; Mabuku et al., 2019). Communities possess significant capacity to exert substantial effect on the behaviors of individuals, encompassing the adoption of disaster-preparedness behavior (Xu et al., 2017). The importance of communities and individuals in emergency preparedness for public health has become increasingly significant in modern civilization due to the severity of natural disasters increases (Adams et al., 2019).Previous study of community effects provides comprehensive, contextual, and meaningful insights into the sociocultural connections between community members and disaster preparedness (Wilson et al., 2018). However, the ability of rural communities to withstand and recover from natural catastrophes, particularly in places that are prone to such events and have limited resources, is largely dependent on the level of individual preparedness.

Literature showed that disaster preparedness among individual living in communities was lack. For example, a Tehran study found that 31.4% of the population lacks adequate knowledge about earthquake preparedness, with 37.2% showing a moderate level of comprehension (Najafi et al., 2019). A subsequent survey carried out in Beijing revealed that people possessed a limited understanding of disaster response, specifically in regard to man-made disasters (Li et al., 2019). A study in Aceh Indonesia revealed a low proportion of people possessing adequate disaster knowledge and preparedness (Ismail et al., 2019). Low awareness of household disaster preparedness exists in Indonesia (Jung et al., 2020). Therefore, it is necessary to increase the community's capacity and participation in disaster management and preparedness by giving them a contextual role. However, there are few studies examining the preparation in disaster management in high-risk areas of Indonesia.

The majority of disaster preparedness initiatives rely on three conventional training methods: informative classroom instruction, web-based training with pre-recorded material, and real-life drills and tabletop activities issues (Putra & Matsuyuki, 2019). An immersive virtual reality simulation is a technology that creates a realistic worldview by combining real and virtual objects (Farra et al., 2019). Augmented reality training provides a realistic, immersive environment that surpasses traditional methods, reducing time and financial constraints for participants and organizations. The majority of previous studies conducted to test the effect of immersive virtual reality simulation focus on the professional degree-seeking

students and first responders with the task involves handling mass casualty incidents, responding to fires, and ensuring chemical/radiological decontamination (Dorozhkin et al., 2017; Farra et al., 2019; Price et al., 2018). Few studies investigated the effect augmented reaility on disaster preparedness among community member (Cao et al., 2017; Kinateder et al., 2019; Smith et al., 2018). Therefore, this study aimed to determine the effect of augmented reality-based education on disaster preparedness among rural communities in disaster-prone area, Indonesia.

METHODS

Study design

This study employed a quasi-experimental with control group and repeated measure design to investigate the effect of augmented reality-based education on disaster preparedness among rural communities in disaster-prone area, Indonesia. This study was conducted in Lembang, West Bandung, Indonesia. Lembang is located in disaster prone area with the present of Lembang fault and Mount Merapi. Data was collected between June to November 2023. Assessment of study outcome was done before intervention (T0), immediately after intervention (T1), and 2 weeks after the intervention (T2).

Sample

The study population consisted of community members in Bandung, West Java, Indonesia. The participants had to meet certain requirements in order to be included in the study. These criteria included being over 18 years old, being able to read and write in Bahasa Indonesia, having a smartphone, and having at least 6 months of experience as a cadre. The exclusion criteria included persons who declined to participate in the research, those with cognitive or mental impairments, and pregnant women. The sample size was determined using G-Power Software version 3.1.6 with a power level of 0.95, moderate effect size, 3 measurements, and 2 groups. The sample size was calculated to detect a 3-point difference in knowledge or practice scores between pre-test and post-test observations, assuming a standard deviation of 6 (Bhandari et al., 2023). The estimated minimum sample size is 120 for each group, and totaling 240. The study used convenience sampling to select participants.

Instrument

The socio-demographic questions consist of inquiries about name, year of birth, gender, educational level, and employment status.

The study utilized the Price et al., (2018) Emergency Management Agency (FEMA) measurement evaluation to assess an individual's level of preparedness for a disaster (FEMA, 2013). Five questions were used to determine this readiness level: participation in relevant meetings, drills, volunteer activities, awareness of the nearest emergency shelter, and self-reported readiness levels. The total score was determined by adding up the points for meetings, drills, and evacuations, as well as the level normalized score, which ranged from 0 to 5. The self-reported level indicated whether the individual had no plans to prepare, had plans to do so within the next six months, had recently started preparing, or had been prepared for at least the past six months. The Cronbach's Alpha in the current study was ranged from 0.466 to 0.732.

Data collection procedure

The study received ethical approval from the Ethical Review Board of STIKep PPNI Jawa Barat (098/III/ETIK/X/2023). A study procedure involves licensed nurses and research assistant (RA) with bachelor

degrees in data analysis and communication skills. RA undergo training on objectives, procedures, eligibility requirements, informed consent, data collection, privacy, confidentiality, and post-study phone checks. Participants were approached by RS if they meet recruitment requirements. Eligible participants sign a written permission form indicating they meet inclusion and exclusion criteria. After assigning participants to either the intervention or control group, researchers and RS conduct baseline measurements. Augmented reality simulation training was provided to the intervention group. A 10-member emergency nursing instructor team was set up, consisting of the experts in medical treatment, nursing care, psychological support and teaching. Some of them had the experience of working on the front line to fight against disaster. The intervention will be conducted at 2-week consisting 3 session each week. The education content was triage, initial assessment, evacuation process, and transportation. The control group not received any intervention but after study finish, they received the same training. Post-test assessment was conducted immediately after intervention and one month after intervention.

Data analysis

Frequency, mean, and standard deviation were computed. An ANOVA analysis was used to determine the average difference in knowledge and practice scores between the preintervention and postintervention periods. The Cohen's d test was utilized to calculate the effect size. The study utilized a Generalized Estimating Equation (GEE) model to assess the intervention's effectiveness over time and identify factors influencing changes in knowledge and practice scores. The GEE approach focuses on estimating population averages rather than variances at different levels, providing coefficient estimates that describe changes in the population mean based on covariate changes (Hubbard et al., 2010). Data coding and analysis were performed using SPSS version 26.

RESULTS

Table 1 shows the demographic distribution in both the intervention and control groups. The average age of the participants was 27.13 years, with a standard deviation of 3.25. Moreover, 52.5% of the participants had completed their senior high school education. The mean period of experience as cadre was 7.35 years with a standard variation of 3.55 years. Around 62.5% of persons were in gainful employment. The control group had a mean age of 26.67 ± 4.65, with 53.3% of individuals having attained a senior high school education. The mean tenure as cadre was 7.94 years with a standard variation of 2.11 years, and around 56.7% of persons were employed. There were no statistically significant differences between the intervention and control groups in terms of age, education, years of experience as cadre, and job position (p>0.05).

Table 1. Demographic comparison between intervention and control group (N=240)

Variables	Intervention group n=120 (%)	Control group n=120 (%)	p-value
Age, years, Mean ± SD	26.67 ± 4.65	27.13 ± 3.25	0.672
Education Attainment			0.134

Primary school	45 (37.5)	40 (33.3)	
Secondary school	63 (52.5)	64 (53.3)	
Higher than secondary school	12 (10)	16 (13.3)	
Employment status			0.076
Yes	45 (37.5)	52 (43.3)	
No	75 (62.5)	68 (56.7)	
Experience as cadre (years), Mean ± SD	7.35 ± 3.55	7.94 ± 2.11	0.228

In the intervention group there was significant improvement of disaster preparedness from 2.56 (SD=1.22) to 4.22 (SD=1.23) at T2 with a modest effect size of 0.42 (Table 2). While in control group, no significant improvement showed at T2 ($p>0.05$). At baseline, there was no difference between the intervention and control groups on disaster preparedness score.

Table 2. Comparison of disaster preparedness scores in control and intervention group at different time points by ANOVA test

Group	**To**	**T1**	**T2**	**F**	**ANOVA Test**	**Cohen's d**
	Mean ± SD	Mean ± SD	Mean ± SD		p-value	
Intervention group	2.56 ± 1.22	4.13 ± 1.71	4.22 ± 1.23	11.65	0.001	0.42
Control group	2.43 ± 13.46	2.51 ± 11.2	2.44 ± 1.35	-1.13	0.231	0.03

Note: before (To), immediately after (T1), 2 weeks after the intervention (T2)

The findings of the GEE analysis revealed a statistically significant interaction between time and group in relation to disaster preparedness (ß = 11.3 (95% CI=5.22 – 14.34, $p < 0.001$) (Table 3). The intervention group (IG) exhibited a more substantial improvement on disaster preparedness at the 2-week after intervention in comparison to the control group (CG) (ß = 5.43, $p < 0.001$).

Table 3. Evaluation of the intervention on disaster preparedness based on the repeated measure analysis using GEE method

Variables	Within group Ref: Baseline		Between group Ref: control group		Interaction [a] Group (IG) x Time Reference group: (CG) x Time		
	ß	p-value	ß	p-value	ß	95% CI	p
Disaster preparedness	4.22	0.001	5.43	0.001	11.3	5.22 – 14.34	<0.001

Note: IG, intervention group: CG, control group; ß: Regression coefficient; Analyses were performed by GEE models, with a Group × Time interaction.

DISCUSSION

This study found that augmented reality (AR) simulation training has potential effect on enhancing disaster preparedness among community members in Indonesia. A study conducted by Fortuna et al., (2023) reported that the results showed that the Blackbox Fire disaster mitigation-augmented reality was successfully displayed as expected (valid) with the target user being the community and students, especially early childhood children building creative, critical, and innovative thinking patterns in solving problems about disasters. Previous studies evaluated the effectiveness of augmented reality wearable glasses for first responder training in mass casualty incident triage, focusing on preparedness and response phases. The glasses displayed a clinical algorithm and an embedded camera for communication with a senior physician, demonstrating potential as a telemedicine and augmented reality disaster response support system (Broach et al., 2018; Carenzo et al., 2018; Follmann et al., 2019). The simulation technology demonstrated potential as a telemedicine and augmented reality disaster response support system, potentially also aiding in the training of first responders (Carenzo et al., 2019). AR is an educational tool that enhances learning experiences by utilizing interactive technology, allowing subject to engage with their environment while retaining subject matter knowledge (McCarthy & Uppot, 2019).

The educational intervention significantly improved participants' understanding and implementation of earthquake preparedness, indicating the importance of encouraging individuals and groups to participate in disaster preparedness measures in disaster-prone areas(Connelly et al., 2021)). Previous study stated that the addition of computer-based learning significantly increased knowledge compared to traditional methods alone (Farra et al., 2019). While, some studies showed that training based on real-life scenarios was frequently comparable to or even lower than that of training based on technology. Studies that compared real-life scenario training to either educational videos (Pouraghaei et al., 2017) or virtual reality (Mills et al., 2020) reported that real-life practice had an impact that was partially lower on knowledge (Pouraghaei et al., 2017). These studies also reported that real-life practice had similar impacts on performance (Mills et al., 2020) and training satisfaction (Mills et al., 2020). When used in conjunction with other methodologies, the training led to results that were comparable in terms of performance (Ingrassia et al , 2015) or somewhat lower (Ma et al., 2021), but resulted in stronger knowledge gain (Ma et al., 2021) than VR training and resulted in lower levels of self-reported competence than serious gaming (McCoy et al., 2019). This study would benefit to Indonesia which experienced multiple earthquakes, potentially resulting in higher knowledge retention rates compared to other studies. Therefore, the inclusion of this instructional campaign in a comprehensive earthquake preparedness program could prove beneficial.

During the AR activities, trainees had the ability to move their avatar around and carry out a number of interventions such as evacuation or breathing and airway checks (Foronda et al., 2019; Ingrassia et al., 2019). Participants used a keyboard to interact with the virtual environment, and screen-based virtual reality training resulted in inconclusive knowledge results but positive performance and self-efficacy (Zhang et al., 2021). AR platforms enable data and video recording of time and action elements,

making them useful for disaster response analysis; they can collect lessons learned and formulate remedial measures for after-action review (Gout et al., 2020; Jung, 2022; Vieira et al., 2019). However, AR-based training and exercise apps may face initial development expenditures as building a realistic environment requires significant time and money. The amount spent on development is proportional to the level of immersion provided by the realism. However, these early development costs are negligible compared to full-scale live exercises and can be recovered quickly.

This study potentially has same limitation. First, the ability to generalize findings is essential to any and all study. This study was only carried out in the province of West Bandung; nevertheless, Indonesia is made up of 34 provinces, each of which experiences a unique kind of natural disaster on a regular basis. Therefore, a study with a comparable design must be carried out in another province if we are going to make the intervention program more rigorous.

CONCLUSION

Augmented reality-based education has potential effect on enhancing individual disaster preparedness in rural communities in disaster-prone area West Java, Indonesia. This study aims to improve community disaster response capacity by providing training to public health centers. The findings could serve as evidence for developing a healthcare policy in Indonesia that integrates disaster preparedness programs with the local community and offers training opportunities for all members, delivered by healthcare system frontline cadre. Future studies are needed to confirm this finding using more robust design and larger sample size.

Declaration

Data Availability Statement

The raw data supporting the conclusions of this article will be made available as requested to the corresponding authors.

Ethics Statement

The studies involving human participants were reviewed and approved by the Institutional Ethical Review Board of affiliated University. The patients/participants provided their written informed consent to participate in this study.

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Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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