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Enhancing Flood Disaster Preparedness Through Virtual Reality: A VR-based Flood Simulator Game

Francisco Maruli Panggabean
Game Application & Technology Program, Computer Science Department, School of Computer Science,
Bina Nusantara University,
Jakarta, Indonesia 11480
fpanggabean@binus.edu

Correspondence: fpanggabean@binus.edu

Abstract *– Flood is a frequent and significant natural disaster in Indonesia. This research aims to increase the preparedness of communities affected by floods through the application of virtual reality (VR) technology. The research followed a three-step methodology consisting of game requirements gathering, design and development, and evaluation. The questionnaire was used to collect game requirements from flood-affected individuals, focusing on their experience, knowledge, and preferences regarding VR disaster simulation. The design and development phase of the game uses the game development life cycle (GDLC) method to create an immersive and informative VR flood simulator. The evaluation was carried out by inviting flood-affected individuals to play and provide feedback through a questionnaire. The results of the study show that the VR flood simulator has succeeded in increasing players' awareness and preparedness in dealing with flood disasters. The user perception questionnaire showed positive feedback regarding knowledge gain, benefits, user friendliness, immersion and smooth performance of the device. Additionally, the in-game scoring system evaluates users' readiness through specific missions, resulting in an average score increase of 25.38% after playing the VR flood simulator. In conclusion, VR flood simulators serve as an effective tool to enhance flood disaster preparedness by providing immersive simulations that align with flood preparedness guidelines.*

Keywords: *Virtual; Reality; VR; Flood; Disaster; Training*

I. INTRODUCTION

In Indonesia, floods are a disaster that often occurs. A flood disaster is an event or situation in which an area or land is submerged due to an increased volume of water (BNPB, 2021). Flood disaster is the most frequent natural disaster in Indonesia. Thus, the capital city of Indonesia, namely DKI Jakarta, is not immune from floods. On February 20, 2021 DKI Jakarta experienced a fairly serious flood disaster because there was data that 312 RTs in DKI Jakarta were flooded with a flood area of 650 km2 and the Mampang area with almost all floods reaching more than 150 cm.

All natural disasters will certainly have an impact on victims and the government, including floods which have an impact that cannot be ignored, including the following, retail entrepreneurs experience losses, Jasa Marga loses income due to the free toll road, the price of used flooded cars has dropped dramatically. Floods can also takes casualties, as in 2020 there were a total of 9 fatalities which were divided into 7 fatalities in East Jakarta, 1 fatality in Central Jakarta and West Jakarta.

To prevent or cope with those negative effects, one of the solutions is to increase the readiness of the people affected by floods. One application of VR is for earthquake disaster training. They uses VR to measure human behavior when an earthquake occurs (Lovreglio, et al., 2017). In the VR that was created, the main goal is to provide knowledge to users about how to respond when an earthquake occurs. The activities carried out by the user will be assessed whether good or bad in responding to the earthquake. Several ways are used to show the consequences of activities

carried out by users, ranging from the sound of people being trapped, broken bones, blood, dizziness, to death (Chittaro & Buttussi, 2015).

VR can also be used for learning (Sattar, et al., 2020). They uses VR on medical students. The study focuses on the benefits of virtual reality (VR) in education and training, particularly in the field of medicine. The researchers developed a VR medical training application and assessed its impact on students' motivation, learning competency, user experience, and perceived competence. The experiment involved 87 students from eight medical colleges and universities. The findings establish a strong foundation for incorporating VR into medical education and training, emphasizing its superiority in user experience, usefulness, learning methodology, and learning competency. The study suggests future exploration of other immersive technologies like augmented reality and mixed reality in medical students' learning. Additionally, it recommends further research on the impact of immersive educational applications on student performance.

VR can also be used to reduce the risk in learning (Moro, Štromberga, Raikos, & Stirling, 2017). The research compares the effectiveness of virtual reality (VR) and augmented reality (AR) with tablet-based (TB) applications for teaching structural anatomy. Participants were randomly assigned to one of the three modes and completed a lesson on skull anatomy followed by an anatomical knowledge assessment. The study found no significant differences in assessment scores between VR, AR, and TB. However, VR participants experienced adverse effects such as headaches, dizziness, and blurred vision. Both VR and AR were found to be valuable for teaching anatomy and promoted increased learner immersion and engagement. The findings suggest that VR and AR can effectively supplement anatomical education.

The research will be divided into 3 stages, looking for game requirements, designing and developing games, and evaluating user readiness in dealing with flooding through the VR games that have been made. The evaluation was carried out by asking the flood-affected people to play VR games. In this game, the user will get a score which symbolizes the user's readiness in dealing with floods.

II. METHODS

The research was conducted in 3 steps:

- *Game Requirement*
  Game requirements will be obtained through questionnaires and analysis of similar applications. Questionnaires will be distributed to users whose areas are affected by flooding. This questionnaire will contain things they usually do when a flood occurs and the game preferences they play. the results of the questionnaire will be used to determine what kind of game will be made. In addition to the questionnaire, an analysis of similar applications was also carried out. this is done to see what applications are closest to the research objectives and observe what are good things and can be applied to the games to be made.
- *Design & Develop*
  Design & develop is carried out using the game development life cycle (GDLC) method. The game design is made based on the results of the game requirements at the previous stage. This stage will produce Game Designs, Use Cases, Activity Diagrams, Class Diagrams, and UI designs. After the game has been made, an evaluation will be carried out on the user.
- *Evaluation*
  Evaluation will be carried out on the user. It will be seen whether the user experiences increased awareness of flood disasters and is better prepared to deal with flood disasters. Evaluation is also carried out on the application in the form of an evaluation of the UI and application usability.

2.1. Game Requirement

Before making the game, the requirements of the game are collected using a questionnaire. This is a collection of questions asked in the questionnaire:

Q1. Have you ever played a VR Game that simulates disaster?

Q2. Do you think it is important to turn off the electronics while flooding happens?

Q3. Do you think seeking warning and evacuation information is important when facing a flood disaster?

Q4. Do you think saving the valuable things to the higher ground is important when facing flood disaster?

Q5. Do you think follow the rescuer's direction is important when facing flood disaster?

Q6. Do you think evacuating to the higher ground is important while facing flood disaster?

Q7. Have you ever used a smartphone-based VR application?

Game requirements are also collected by comparing several VR based games. Those games are Natural Disaster VR, Earthquake Simulator VR, and House Flipper VR. Based on the results of the questionnaire and comparison of similar applications, it was concluded that a game would be made with the following specifications:

- Designing and creating game applications based on virtual reality for the first response to flood disasters
- Make a game with the information data that has been obtained from the respondents
- Designing and creating games that have a scoring system with the aim of testing the user's readiness in dealing with flood disasters
- Design and build games with immersive gameplay
- Provides hints while the user is playing the game
- Give tasks in the game to get score

2.2. Evaluation

The games created are then evaluated. The evaluation carried out is an evaluation of user needs and the User

Interface. This evaluation is carried out on people living in flooded areas. Evaluation is done by allowing users to try VR games and giving them questionnaires. Below is a list of questions asked:

E1. I got new knowledge about flood disaster
E2. I feel benefited after playing the VR flood simulator game
E3. VR flood simulator game has user friendly game mechanics
E4. I find Game VR flood simulator immersive
E5. I feel my device is smooth when playing the VR flood simulator game

The game also has a system score. This system is used to measure whether the user can cope or respond if a flood occurs. This score will be used to see the user's readiness in dealing with flooding. To measure readiness, we also implementing these features as a quest. The quest collectively give a maximum of 80 points. We measure the points every time the user played the game:

F1. Search information about flood disaster
F2. Shut down the electricity
F3. Secure the valuables in a scene
F4. Follow the rescuer's directions
F5. Evacuate to the save place

III. RESULTS AND DISCUSSION

This research produces a VR game that can be played using a smartphone. The screen will be split into 2 section in Figure 1. Interaction is carried out by the user using "gaze input", where the user must see a point within a few seconds to interact with that point. Flood Simulator game players are required to complete all tasks given by the game system. Each task completed, the player will be given a score which is useful as a benchmark for the level of player readiness in dealing with flood disasters in the real world. In carrying out tasks, players can interact with several objects in the Flood Simulator game world. Tasks that have been successfully completed will change color to green, a sign that the task has been successfully carried out by the player, conversely when the color of the writing on the task list is still red, then the player has not completed the task. Flood Simulator game players will be given two hundred (200) seconds to be able to complete all the tasks given.

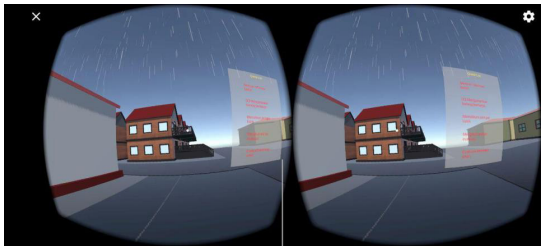

Figure 1. Screen split in VR Game

VR game played by 41 people. After playing, the user will be asked to fill out a questionnaire about the user's needs for the game being played. This questionnaire was created to determine user comfort in playing mobile phone-based VR games. In Table I, there is data showing the results of the user questionnaire on a Likert scale from 1 to 5, where 1 is Disagree and 5 is Agree.

Table I. User Perception Questionnaire

No	1	2	3	4	5	Avg
E1	0	0	5	20	16	4.27
E2	0	1	5	15	20	4.32
E3	0	0	3	18	20	4.41
E4	0	0	3	17	21	4.43
E5	0	1	6	13	21	4.31

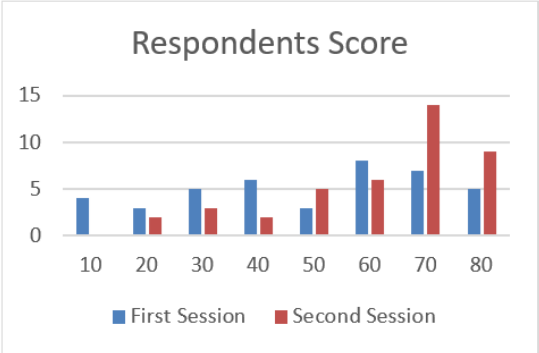

Figure 2. Respondents Score

Respondents were given the opportunity to play twice. The first opportunity is when respondents play games with their previous knowledge. The results of the game are stored in the form of a score. The score was then compared with the score when the respondent played a second time after getting information about the flood disaster in the game. The results of these scores can be seen in the Figure 2. We found that after the second play session, respondents got an increasing average score from 49.02 to 61.46 or 25.38%.

IV. CONCLUSION

Flood Simulator can prepare players' readiness in dealing with flood disasters by providing flood disaster simulations in accordance with flood preparedness guidelines for the community. By applying the flood preparedness guide (F1 – F5) into a simulation game based on virtual reality (VR) games, it will make it easier for players to absorb and understand the information provided in written form in the guide. This can be proven by the value of User Perception questions in questions E1 to E5 which have a value above 4.

VR Flood Simulator can improve preparedness in dealing with flood disasters. The percentage increase in the average score when players first played the Sunday Flood Simulator game and the average score after playing the Sunday Flood Simulator game was 25.38% from 41 respondents who used the VR Flood Simulator game application.

For future research, interactions can be added using VR technology that uses a controller so that the user's movements can be more free. To increase the user's immersive level, the art style used should also be made more realistic.

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