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Long Paper

Development and Evaluation of TYFIREQUAKE: A Virtual Reality Simulation for Disaster Preparedness of Children

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Abstract

Purpose – This study aims to develop and evaluate TYFIREQUAKE virtual reality simulation of fire, earthquake, and typhoon scenarios using Virtual Reality (VR) as an alternative training tool and application for increasing the level of disaster preparedness to be able to apply the safety and precautionary measures in emergencies.

Methodology – The proponents applied the Rapid Application Development (RAD) model as a software development model and followed the different phases such as outlining the requirements, user designs and input, constructions, and finalization of the software. The study incorporates different software for creating virtual environments, layout designs of scenarios, characters, controllers, interactive elements, and AI non-player characters. The system developed the desired output and functionalities like presenting the Before, During, and After scenarios of each disaster with time monitoring and assessment

Results – Moreover, it was evaluated using test cases such as functionality case testing, sharing test, installation, and load test, portability test, performance test, and system test wherein the system Passed all tests. In this study, the design for simulated training on the disaster was discovered to be capable of exposing a person to a disastrous environment without endangering the person immersed in the condition.

Conclusions – This virtual training program for earthquakes, fire, typhoons, and tsunami/floods can be used without a cost or by spending a lot of money on deploying real-life trainers and equipment for physical drills. The results of this study suggest that a similar design for a larger community may be provided to local cities mandated by the government to propagate disaster awareness and emergency preparedness programs.

Recommendations – It is suggested that the developed mobile application can be implemented in emergency response teams as a tool for disseminating awareness of disasters, especially to the children. Additional features that can provide feedback, a database as a repository of data and information for crafting more insightful ideas in generating activities on disaster prevention.

Research Implications – The TYFIREQUAKE mobile application could be an effective training tool for equipping children with sufficient knowledge and skills in responding to typhoons, fires, and earthquakes. They can learn the proper strategies for coping with disasters specifically in identifying the possible safe places, maximizing the available resources, and action plans for recovery before, during, and after the disasters.

Keywords – disaster preparedness, earthquake, fire, RAD, typhoon, virtual reality

INTRODUCTION

Being located in the "Pacific Ring of Fire," the Philippines becomes one of the most vulnerable countries to experience frequent calamities and disasters. The topographical area of the Philippines makes the country remarkably powerless to a huge number of dangers including discontinuous tropical storms, seismic tremors, and volcanic ejections which are universally viewed as the deadliest and costliest risk (Dollete, 2020). Also, The Philippines is among the highest weak nations to cataclysmic events and environmental impacts. In the year 2020, the nation encountered a volcanic emission, a progression of serious seismic tremors, and progressive tropical storms that immersed more than 60 towns and urban areas (Mina, 2021). The Philippine Risk Profile for Natural Disasters is also reflected in the 2011 Global Assessment Report that the country places third out of 173 countries and ranked 3 with 27.98 risk percentage as to exposure to hazards such as

cyclones, earthquakes, tsunamis, floods, and landslides (United Nation Office for Disaster Risk Reduction, 2012).

Disaster risk is the probability of harmful consequences of exposure to hazardous conditions which may result in damages to livelihood or property or loss of life. Increasing risk can be managed by proper planning and by conducting appropriate training in disaster management (Caballero and Niguidula, 2018). No one can foresee when a calamity like an earthquake, fire, or flood will occur precisely. Everybody should be set up as debacles can happen anyplace at home, in the working environment, or at school. At the point when a debacle occurs at school, everybody ought to be set up to deal with it successfully (Corpuz, 2019). The people do not know what appropriate action to undertake; they just have to judge the best way to evacuate in an emergency. Even though structural buildings such as schools, houses, offices, and others are made by the experts like planners, designers, architects, and engineers have to design buildings to support them. However, those experts also lack knowledge and experience with the disasters (Takeichi et.al, 2018).

The Philippines experienced major catastrophes like Typhoon Haiyan (Yolanda) caused 6–7 m high storm surges in 2013. It was the strongest tropical cyclone and the deadliest disaster in Philippine modern history sparking catastrophic damage to coastal communities (Center for Research on the Epidemiology of Disasters 2014 as cited by Dalisay and De Guzman 2016; Nakamura et al. 2016). Haiyan exposed the low level of disaster preparedness and response capabilities of many local governments. Although the government has operational Disaster Risk Reduction Management (DRRM) programs, made ample preparations, and braced themselves for the worst, they were simply crushed and overwhelmed by the scope and enormity of the destruction (Dariagan et al., 2021). Moreover, Bringula and Balahadia (2019), presented the increasing fire incidence in Manila which exhibits a pattern in terms of location. Faulty electrical connections are the major cause of fires throughout the year and in the 14 municipalities of Manila. LGUs and government agencies can utilize the findings of this study in developing fire prevention programs for the municipalities with the highest incidence of fires. In the article by Giroux (2013) in ReliefWeb, he stated that in case of an earthquake or landslide, most people are not aware of what to do and how to react. People are left with nothing and they just do not know where to get help and how to face these emergencies. As a result, panic often increases the number of deaths and injuries. Right now, there is no all-inclusive meaning of individual catastrophe readiness, yet in the writing, there are two operational constituents of individual readiness: arrangement of a survival pack and production of a family crisis plan (Juanzon & Oreta, 2018).

Calamities and disasters do not only cause injuries and damage to properties but also to mental health. In a report, Dr. Jullie Hall observed a significant emergence of mental health problems due to the loss of loved ones, loss of properties, and livelihood after experiencing Typhoon Haiyan (Geronimo, 2014). These experiences exacerbate the onset

of common psychological disorders such as major depressive disorder, posttraumatic stress disorder, suicidal behavior, and anxiety disorders (Pietrzak et al., 2012; Udomratn, 2008). Mental health problems significantly influence the functioning of a person in various aspects of life. It affects their work, and relationships with others and themselves. Furthermore, research evidence has shown that those people who have probable serious mental health problems were characterized by a lack of disaster preparedness and emergency plan (Eisenman et al., 2009). This means that individuals who are not prepared for any unpredictable disasters are prone to mental health problems. Therefore, people must possess sufficient knowledge in preparing for any kind of calamities and natural disasters to prevent adverse consequences, both physical and psychological.

Disaster awareness initiatives may consist of individual activities such as touring villages to conduct earthquake awareness meetings or posting earthquake, fire, and typhoon preparedness posters at a school or barangay hall. It is useful to integrate disasters and evacuation simulations and visualize the real scenarios of disaster. Simulation of disaster scenarios may also be employed to increase awareness of the people of the community such as the emerging Virtual Reality technology. The introduction of technologically-based approaches to disaster response training via Virtual Reality (VR) environments appears promising in its ability to bridge the gaps of other commonly established training formats, in which VR offers realistic quality that is not generally present in classroom-based or web-based training, but it has cost advantages over large-scale real-life exercises and is gaining increasing acceptance (Hsu, Li, and Bayram 2013).

Moreover, this technology is useful in the preparations of a mock drill for disaster management training, which is mostly not possible or feasible to recreate either due to being inherently unsafe, regulations-wise disallowed or incurring significant people and assets (Pimpale, Prabakaran, & Kannadasan, 2018). Some studies focus on the effectiveness and efficiency of using Virtual Reality as the main tool in preparing for disasters and calamities. For instance, Caballero and Niguidula (2018) showcased the simulations of different disaster deals by giving guidelines on "before", during" and"after" incident activities. Similarly, Takeichi et al. (2018) used the VR for evacuation simulation on various disasters while Sermet and Demir (n.d) discussed the Flood Action VR that provides an interactive environment for training and education on flood disaster preparedness only. Lastly, Prabakaran and Kannadasan (2018) applied VR in disaster response training on fire incidents. In other words, VR can be a useful tool in increasing the disaster preparedness of individuals, thus, preventing the negative consequences caused by ineffective emergency responses to calamities and disasters.

In this study, the focus was on the children. Compared to adults, children are at a higher risk of getting involved in accidents and experiencing other adverse consequences of disasters that may threaten their lives (Lai & La Greca, 2020; Kousky, 2016). According to Lai and La Greca (2020), children ages 18 years and below are more vulnerable to long-term

physical, psychological, and educational problems resulting from exposure to disasters. In a meta-analytic study, Tang and colleagues (2014) have found significantly higher rates of mental health problems among children compared to adults. They experience these insurmountable adverse consequences because of a lack of knowledge and skills in disaster preparedness. The only way to alleviate its impact is to train and educate them. Thus, the current study leads the proponent at helping children acquire sufficient knowledge and skills in preparing and responding to disasters by learning through virtual reality simulation training and equip communities, especially the children with sufficient information about the safety and precautionary measures before, during, and after disasters.

This study aimed to seek to achieve the following: a) develop a mobile application named TYFIREQUAKE that simulates the fire, earthquake, and typhoon through Virtual Reality and b) evaluate the performance of the developed system using the system test casing such as Functionality tests, Sharing Test, Installation Test, Load Test, Portability Test, Performance Test, and System testing.

METHODOLOGY

The TYFIREQUAKE virtual reality simulation was developed to provide a comprehensive and fun training ground for children who are experiencing a lack of knowledge and skills in responding to disasters. It started with the conceptualization phase of the structural design and content. The structure refers to the way the user will navigate the program such as the different buttons, features, and the overall layout of the program. The content includes information about the different disaster responses before, during, and after the event. The proponents interviewed the experts from the Laguna Provincial Disaster Risk Reduction Management Office (PDRRMO) that were in-charge in educating the communities in Laguna to help mitigate the devastating impacts of various disasters. Information regarding the proper responses to fire, earthquake and typhoons were the topic of the discussion. Pamphlets, magazines, and other relevant materials used by the PDRRMO were obtained for the comprehensive collection of data and information regarding the different disaster-response activities and programs such as proper utilization of available resources during disasters, and preparedness campaign and post-disaster response training and seminars. The interview was conducted to obtain information about disaster preparedness from the experiences and specialization of first-hand experts in the field. Their expertise is essential in the development of a comprehensive program by providing suggestions and recommendations on how the TYFIREQUAKE virtual reality simulation will be effective and beneficial to its users. In other words, the TYFIREQUAKE virtual reality simulation was developed through collaborative efforts and inputs from the experts in disaster preparedness.

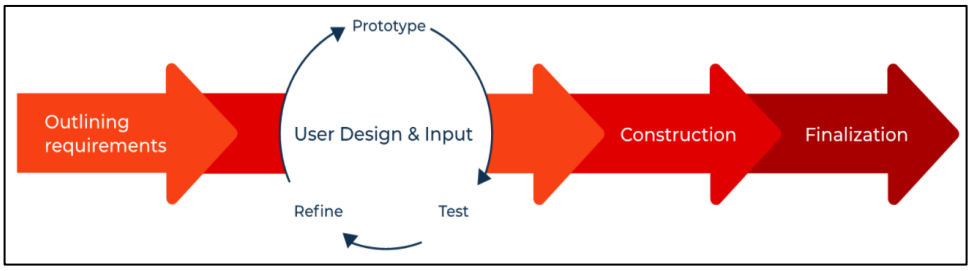

Figure 1. Rapid Application Development Model (Source: creatiio.com/RAD)

After the collection and analysis of disaster-related response information and benchmark to different existing systems, the proponent proceeds with the development of the system. This phase aims to integrate the appropriate process, information, features, and software needed for the program. After the system was developed, the researchers underwent testing to assess the functionality, portability, reliability, and performance test casting of the FireQuake Virtual Reality Program.

The proponents applied the Rapid Application Development (RAD) model as a software development model for this study. RAD is a software design methodology that's designed to counter the rigidity of other traditional software development models, where you cannot make changes easily after the initial development is complete. According to new research, (2022) rapid application development is also heavily focused on keeping the end-user involved throughout the entire stage of the development process with rapid application development; developers can make multiple iterations and updates to software quickly without starting from scratch each time. This helps ensure that the outcome is more quality-focused and is in alignment with the end-user's requirements.

To develop a simulation type of application, testing was frequently done and changes on input were always needed. RAD methodology is designed to be flexible to changes and to accept new inputs, like features and functions, at every step of the development process. Figure 1 are the phases of the RAD model: (1) Outlining Requirements, (2) Analyzing User Design that deals with building prototypes, testing, and refining, (3) Construction leads to implementing the feedback by the users through coding, testing, and development tasks, lastly (4) Finalization, which is the developed system undergone testing, conversion, interface, or user training.

To develop the TYFIREQUAKE the proponent used different software packages such as the following: The Visual Studio 2017 is used for compiling the different modules of the system such as codes and methods applied and it supports many programming languages and mark-up language. In terms of programming language, C Sharp Programming (C#) was utilized because it is an open-source general-purpose scripting language that is especially suited for unity game engines and simulation. Moreover,

Substance 3D Painter is also utilized to texture into 3D assets, from advanced brushes to Smart Materials that automatically adapt the model which the system builds different models and objects within the VR simulation. Autodesk MAYA is used to create assets for interactive 3D applications and visual effects. The user interface of the application is customizable so that a personalized workflow could be created. Finally, Unity Game Engine is used as a tool in scripting API in C#, for both the Unity editor in the form of plug-ins and games themselves, as well as drag and drop functionality.

The simulation has been developed through Unity Game Engine, which is an open-source game engine allowing for integrated gameplay design, programming as well as modeling, and texturing. The engine allows C++-based programming, which makes it convenient to make class-based objects in-game and design an environment that has different properties but can still inherit some common ones. For instance, in this scenario, a variety of objects in the world can dynamically execute different animations and events with just a simple function or script.

LAYOUT DESIGN

For the first scenario, a generic house building is depicted. The architectural layout plan of several home spaces and locations was reviewed to identify the key elements present in most of them, like rooms with furniture, lobbies, fire exits, and others to replicate a layout as presented in Figure 2. Universal signs and symbols are used in the simulation as guiding references, for instance, the instruction "storm guide (gabay sa bagyo)" can be used by children to be guided by needed actions to perform during a storm or typhoon. These signs, symbols, and instructions can guide them towards acquiring skills and knowledge about disaster responses.

Figure 2. Screenshots of Layout Design of TYFIREQUAKE

The house floor is designed using Unity Engine itself, which allows transforming static meshes into desirable structures with materials. To make the layout more identifiable from its basic structure, items like lamps, furniture, and others are added to the rooms in which items are interactive in various ways like in the study of RajitPimpale and colleagues (2018).

CHARACTER CONTROLLER

Inside the simulation, the trainee can view in a first-person mode with a VR device and cardboard, i.e. projection through the character's sights. The character movement is carried out by the movement of the VR device. The character will always move forward whenever a player looks at the floor direction that they want to move on using the controller shown in Figure 3. To move something ("paano gagalawin o gawiin and isang bagay"), stare at the toothed wheel or circle until it finished the process ("titigan hanggang matapos ang proseso) or until it changed permanently.

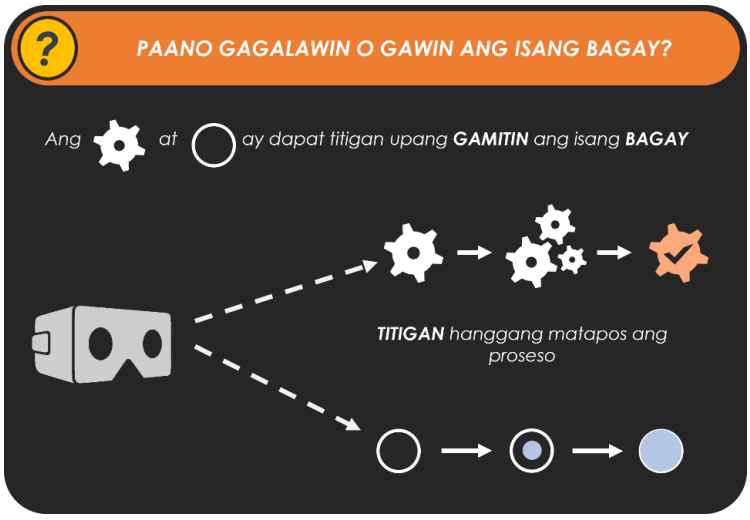

Figure 3. VR Controller Guide

C. Interactive Elements

1) *Interactable objects:* all interactable objects were built with just a single script. The object itself has its animation clip and animator controller that has been manipulated using a script. The script is the one that will handle the detection range and the interaction sensor for the engine to be able to tell if it is time to execute some animation. Every object animation has an event function that will trigger every time the last animation key will play presented in Figure 4.

2) *Objects with timer:* some objects needed time to finish their event. A cooldown UI was imported and designed to show the user that some events needed time to finish shown in Figure 5. For instance, the third picture on the right shows instructions like "remember! Wait until food becomes well-cooked, then turn of the gas stove after (Tandaan! Intayin muna maluto and pagkain, patayin ang kalan pagkaluto ng pagkain)." Here are some algorithm codes used in the system.

Figure 4. Interactive objects in the system

```
public GameObject itemtoshow;
    public float delaytime;
    // Start is called before the first frame update
    void Start()
    {
        StartCoroutine("delayshow");
    }
    IEnumerator delayshow()
    {

        yield return new WaitForSeconds(delaytime);
        itemtoshow.SetActive(true);

    }
```

Figure 5. Timer during the system interaction

3) Survival Bag and objects: there are interactive scripts that list the essential things and objects for survival. However, these essential things and objects are scattered everywhere. The bag has a sensor that detects and gets the object that the user wants. It also includes a UI list for the object that is needed to be put inside the bag. A check script has been attached to the bag to see and check if the user meets and gets all the needed survival objects shown in Figure 6. For instance, the interactive script shown in the right picture lists the earthquake survival things such as a blanket, water, gloves, food, whistle, flashlight, medical kit, and radio.

Figure 6. Survival Kit in Simulation

4) *AI NPC/Person:* Nonplayer character or NPC was scattered in various places and times in the simulation field to help users to feel more panic and reality. The AI of the NPC was designed with a dynamic animation event where they can interact with the events happening in the environment shown in Figure 7. They can flee to safe places and avoid dangerous events.

Figure 8. Results of VR Simulation

D. End Results

Causes and effects results: when users finish some simulation event. The results scene will show up and show the cause and effects based on the action of the user in the simulation. There is a script that dynamically checks the user's action every time they do something in the simulation or task.

End results details: there are results UI that will pop up after you finish the overall simulation. This UI will show all the details about the action that you've done when simulating. It includes the status if you finish some tasks, how much time the user finishes a task, and if the user passed the task which is revealed in Figure 8. For instance, the left picture shows three action outcomes with labels each such as "many people survived because of the sound of the alarm (Nakaligtas ang madaming tao dahil sa tunog ng alarm)", "the fire was stopped and did not spread due to the use of the correct extinguisher (Napahinto at hindi kumalat ang apoy dahil sa paggamit ng tamang pangpatay)", and "The fire did not spread immediately because the closed door blocked it (Hindi agad kumalat ang sunog dahil naharangan ng pintong isinara)." In the right picture, it shows two unsuccessful and one successful action outcome. The first failed attempt says "the house may collapse if not strengthen. It is possible that someone will be injured or die (Maaaring gumuho ang bahay kapag di napatibay. Posibleng may masugatan o mamatay.)", the next successful attempt states that "Nothing major harm happened to you because of the good plan (Walang anumang malaking pinsala ang nangyari sayo dahil sa mahusay na plano.)", and the last unsuccessful attempt results reveal that "with no or lack of a survival kit, one may suffer or die. (Dahil sa wala o kulang ang survival kit, maaaring mahirapan o mamatay ang isa.)."

E. Testing and Evaluation

The pandemic that happened during the development of this system caused users to not use the system to its full potential. This made it difficult to measure the effectiveness of the system, which hindered the ability to improve it further. This is a major setback in the development of the system. However, it is also an opportunity to learn from the pandemic and adjust the system so that it is better suited for the needs of the users. In line with that the proponents' test casing to evaluate the developed system. The primary purpose of the test casing was to demonstrate the functionality of the system and to gain an understanding of the performance of the system in depth. A series of tests have been conducted to demonstrate the functionality of the system at this depth.

The testing includes Functionality Test, Sharing Test, Installation Test, Load Test, Portability Test, Performance Test, and System testing. To avoid bias in the evaluation of the system the testing was witnessed by some colleagues and recorded all the results in an excel file The system was tested for a minimum of two weeks to ensure that it is stable, reliable, and has no bugs. The test results were analyzed and compared to expected performance using the test casing evaluation format, including the use of spreadsheets, and tables to determine if the system provides the correct information and performs its functionality based on the objective of the study.

TYFIREQUAKE: System Architectures

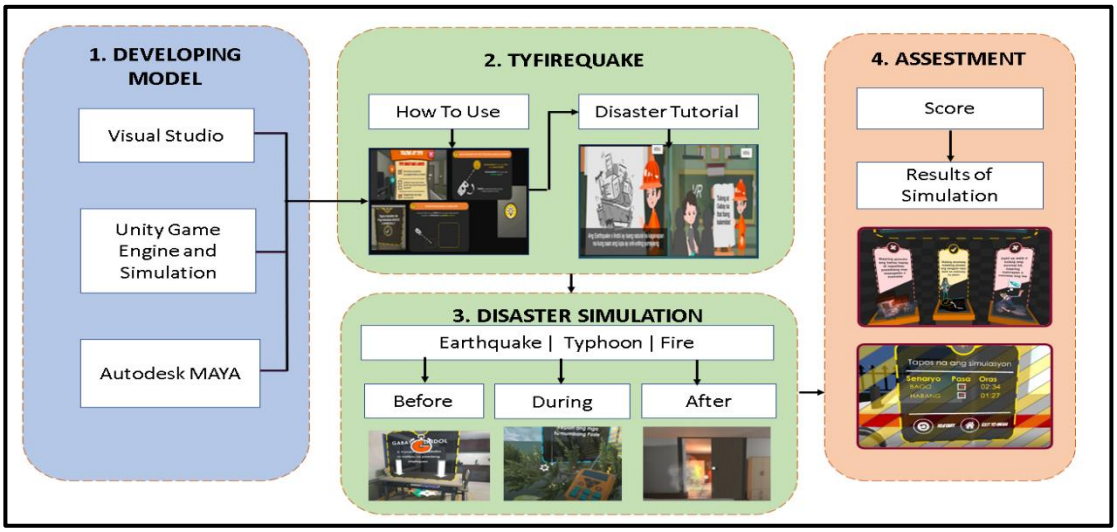

Figure 9. System Architecture of TYFIREQUAKE

The project is created in the form of simulation through VR in which the player/user wearing the virtual reality device, would assume the role of a person encountering a specific disaster like fire, earthquake, and typhoon. In the development of the system, the

proponents utilized various tools such as Visual Studio, Unity Game Engine and Simulation, and Autodesk MAYA. TyFirequake uses Virtual Reality, VR creates an entirely digital environment, a 360-degree, immersive user experience that feels real. In a VR setting, users can interact with what they see as if they were there; this feature will be more entertaining and also more interactive. The use of this technology will help engage more users to the application, thus, more people will be open to Disaster Preparedness which is the main goal of the Application.

The system has been divided into four (4) parts for the said disaster such as a) How to Use, b) Disaster Video Tutorial, c) Disaster Simulation, and d) Assessment

Figure 10 displays the disaster simulation via Virtual Reality. The **Bulb Icon** in the system gives the tips on *how the system should be used* such as a.) how to move, and walk in the VR, b.) how to look at different hints and help in assessing the VR simulation c.) how to move or do the instruction in the disaster scenarios and d.) how to be trained to easily do the task in the simulation.

The upper right picture in Figure 10 shows the content after clicking the help button. It says "where to find tips or help on things to do (Saan hahanap ng tips o tulong sa mga gagawin)." The Lower left picture shows the list of help and tips (tulong at tips). The lower right picture presents the game style, whether through VR (virtual reality) or joystick.

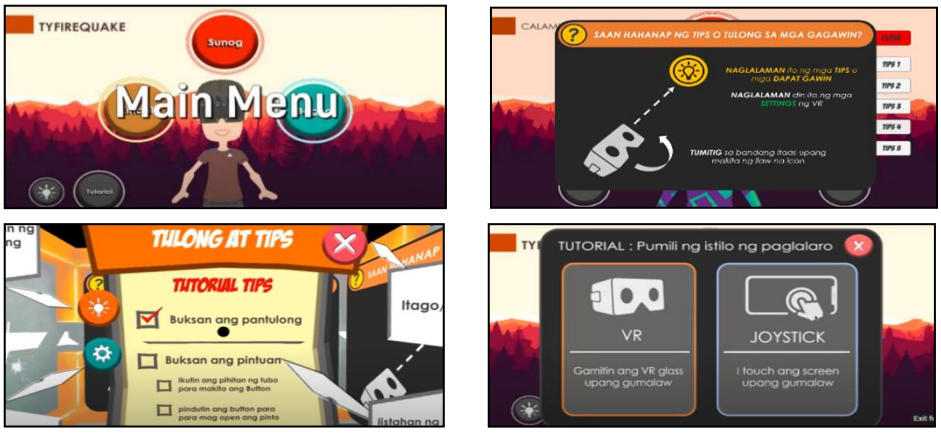

Figure 10. TYFIREQUAKE Menu and Tutorials

Moreover, in terms of the Disaster Video Tutorial, the user will be sent to the main menu where there will be three options shown in Figure 11. These options are earthquake (lindol), fire (sunog), and Typhoon (bagyo) (as shown in the upper left picture). Each option has its introduction, tutorial, storyline, and gameplay. To experience the virtual environments of different disasters, the user should tap the chosen disaster.

Before going to disaster simulation it has a video play button that can be used by the user to learn about the different disasters. Informative videos provide useful and interesting information about earthquakes, fire, and typhoons to enlighten the users about the importance of disaster preparedness and what to do, "before", "during", and "after" when a phenomenon occurs. The informative videos shown in Figure 11, discusses the description of each disaster, its cause, and the possible outcome of each phenomenon. The video animation is in a form of animation in which the character is an average young boy named "Juan" just walking outside and ends up learning so many things from the Seminar using VR Technology. Just like what the pictures in Figure 11 depicted. The upper left picture labels can be translated as "Hayyy… It's boring, I'll just get out (Hayyy… Nakakatamad naman, makalabas nga)." The animated information presentation consists of 3 booths; Earthquake, Fire, and Typhoon. Each booth has its discussion about Disasters.

The upper right picture explains the definition of an earthquake which can be easily understood as "an earthquake is a natural event in which the earth gradually shakes (Ang earthquake ay isang natural na kaganapan na kung saan ang lupa ay unti-unting yumayanig)." The third picture in the lower right position explains that "a fire is a massive blaze or raging fire that can gut thousands of properties (ang sunog ay isang malawakang paglagablab o pananalasa ng apoy na maaaring tupukin ang libo libong ari-arian)". The last picture in the lower right narrates that "the storm is a climate that carries strong winds and heavy nap and rain that can cause flooding (ang bagyo ay klima na may dalang malalakas na hangin at mabigat nap ag-ulan na maaaring maging sanhi ng pagbaha)". The use of these animations and character role plays provides more entertaining graphics to the users, especially the children.

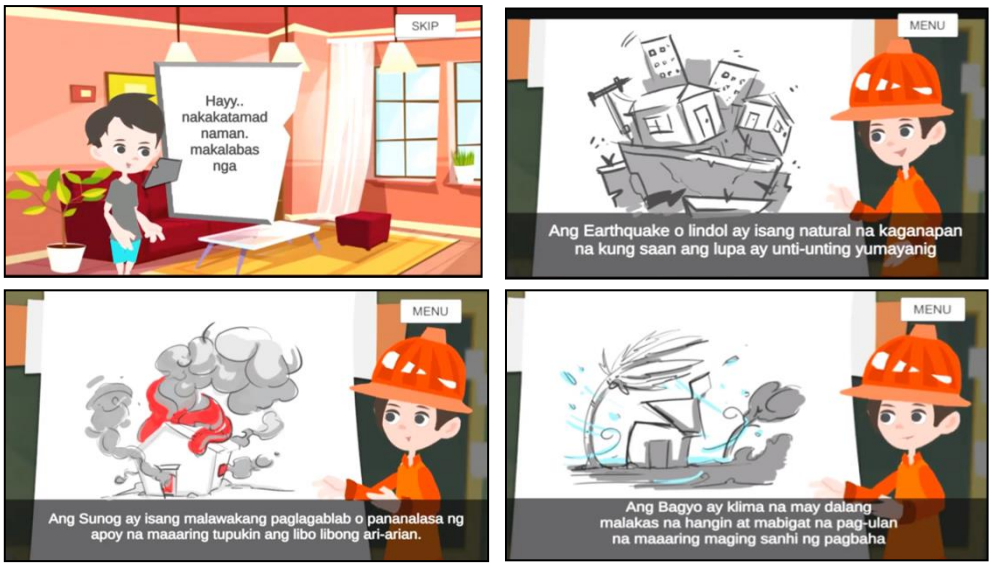

Figure 11. Boot Camp as Disaster Information

The **VR Disaster Simulation** part will provide possible scenarios of the disasters. Upon start, the character would be placed in a generic environment (for example, an office building), which has been hit by or is going to be hit by an emergency (e.g. house or apartment within a building).

The scenario also contains some realistically placed interactive objects that the character can use to increase chances of survival, while also warning the user of some of the common hazards that can be caused due to lack of awareness. In each scenario, it includes various types of safety procedures wherein the user will apply what he learned in the Tutorial Module which discusses the BEFORE, DURING, and AFTER activities in the occurrence of the disaster.

In the **VR Assessment,** in this part of the system, there are interactive objects to add realism to the simulation, it also increases the scope of the simulation by increasing its control difficulty and increasing awareness to survive. The user's virtual character will be free to choose what action to be taken and once you made a wrong decision it will display what consequences or effects will happen. This imbibes learning into the users' minds not only about the things they are supposed to do in case of any such disaster but also about the things they should be careful not to do.

RESULTS AND DISCUSSIONS

VIRTUAL REALITY SIMULATION

TyFirequake is a mobile application that uses virtual reality simulation for the real-life experience of natural disasters such as; earthquakes, Fires, and typhoons. The application is an informative game that teaches the users to be prepared if ever natural disasters occur.

EARTHQUAKE VR SIMULATION

In the Earthquake Virtual Environment, there is a storyline on the earthquake where the person is living in the house beside the mountain and there is an announcement on the Television that a possible earthquake might occur. Once the storyline is done the simulation will start, and the user now will apply what he/she learned in the Disaster Video Information Button presented in Figure 12.

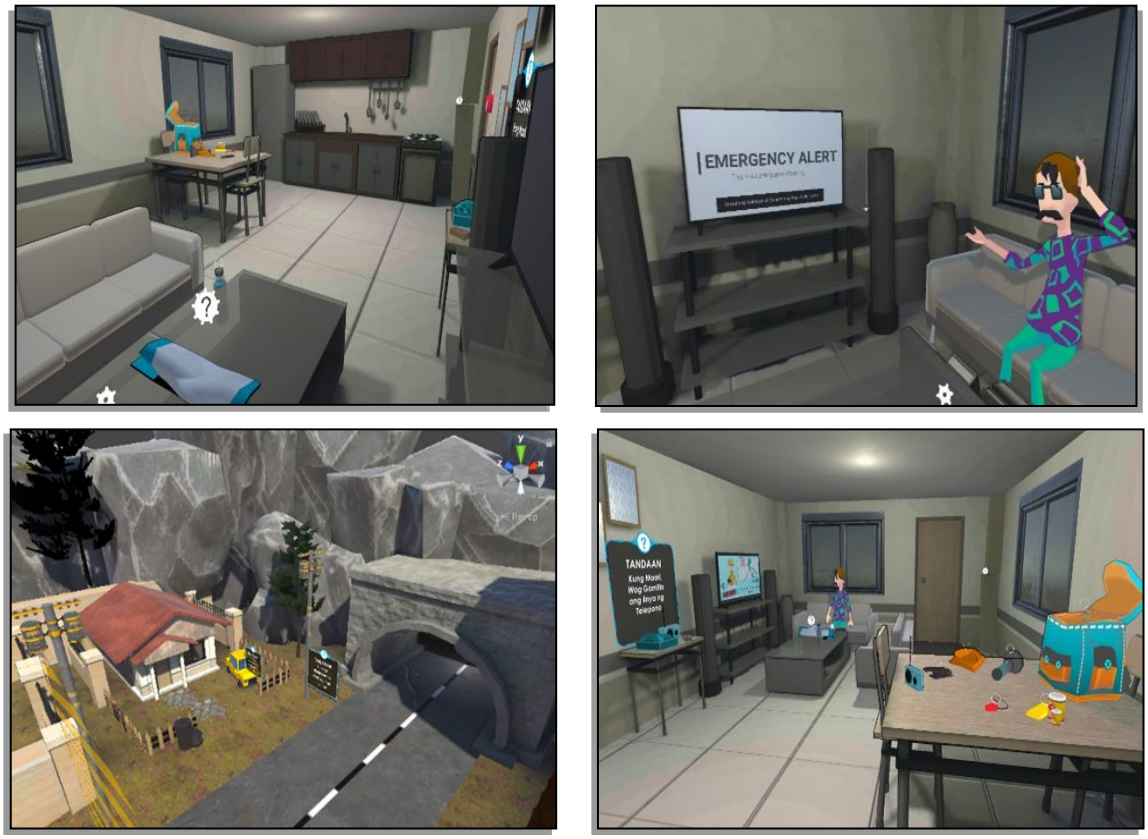

Figure 12. Earthquake VR Environments

During the simulation, the user should determine the appropriate actions. The system has time monitoring to provide information on how long they accomplished the scenario in the VR environment, where users can explore or go around the house to identify the different things to do where there is also a Hint icon that can help them to assist, each of the action taken by the user will be recorded to assess what he/she accomplish in the simulation.

Figure 13. Earthquake Simulation Tips

Figure 13 shows different things to do BEFORE the earthquake such as preparing the survival kits (upper left picture), creating a plan if the earthquake occurs, and adding more protection to the house. The user must get all the survival kits based on the list and do the necessary action before the disaster.

In the upper left picture, it shows the "tips before earthquake (tips bago ang lindol)" such as create a plan for preparation to earthquake (gumawa ng plano sa paghahanda sa lindol)", "strengthen houses, fix broken parts of the building (patibayin ang mga bahay, ayusin ang mga sirang parte ng gusali)", and "prepare survival kits, prepare a bag to hold necessities (maghanda ng mga survival kit, maghanda ng bag na mapaglalagyan ng mga kailangan gamit)". The lower left picture shows a checklist of earthquake survival kits like a blanket, water, gloves, food, whistle, flashlight, medical kit and radio. The lower middle picture depicts the checklist and the use of the things that will be picked up like "blanket helps to protect the body from hot and cold temperature (Blanket: tutulong upang maprotektahan ang katawan sa mainit o malamig na temperatura)". The narrative in the lower right picture can be translated as "are you done preparing before the earthquake? (tapos ka na bas a paghahanda sa bago lumindol?)".

Figure 14. VR Simulation During Earthquake

Moreover, Figure 14 also shows that the system provides earthquake simulation about the appropriate action "DURING" earthquake which is the DROP, COVER, and HOLD. The use of the survival kit will help the user to survive the earthquake incidents.

The checklist about the "tips during earthquake (tips habang lumilindol)" as shown in the upper left picture can be translated to the following: "lie down and hide in strong objects/structures (dumapa at magtago sa matibay na bagay)", "get out of the house when the earthquake stops (lumabas ng bahay kapag tumigil ang lindol)", and "go to a safe place where nothing will fall on you (pumunta sa ligtas na lugar kung saan walang bagay na pwedeng bumagsak sayo". The label in the upper middle picture can be translated into

"earthquake guide (gabay sa lindol)" and "bend down and go under a strong structure (yumuko at pumailalim sa matibay na pwedeng pagtaguan)". The lower left picture contains label that says "get out (get out)". The lower middle picture can be understood as "remember, do not drive during earthquake (tandaan huwag magmaneho kapag may lindol" and "tandaan do not enter inside the tunnel (tandaan huwag pumasok sa loob ng tunnel)". In the last lower right picture, the label can be translated as "remember do not enter inside the old and broken buildings (tandaan huwag pumasok sa mga luma o sirang gusali)".

Figure 15. Earthquake VR Object After Simulation

Finally, the user will now apply the information she/he gained in the video disaster tutorial regarding the steps to do AFTER the earthquake occurs. Users can follow or not some of the Hints or Information signs in the simulation revealed in Figure 15. The system has the additional features of FX and animation of earthquake intensity and the advanced Artificial Intelligence Reaction of the people in the disaster incident which is an earthquake.

The first picture lists the tips after earthquake (tips pagkatapos lumindol) such as "help other people in need (tulungan ang mga nangangailangan ng tulong)", "listen to radio for news (makinig ng radio para sa balita)", "report immediately your current condition to the nearest station (ireport agad ang iyong kalagayan sa pinakamalapit na istasyon)", and "remember, avoid using your telephone lines (Tandaan: Kung maari, wag gamitin ang linya ng telepono)". The second picture says "remember: help others if possible, you can also seek help from others (tandaan: tulungan ang iba kung possible sa kalagayan, maaari ka rin humingi ng tulong sa iba para tulungan ang nangangailangan)". Lastly, the third picture reminded the user to avoid using telephone lines (tandaan: Kung maaari, wag gamitin ang linya ng telepono)".

Fire VR Simulation

In the same approach in the earthquake simulation in VR, the fire simulation will be presented virtually using the mobile application. The fire simulation was composed of scenarios and virtual environments where the user will interact as shown in Figure 16. The first part of the simulation is to apply the appropriate things in avoiding fire incidents like

turning off gas tanks, and keeping candles and match sticks from children presented in Figure 17. For instance, the first picture in the upper left position in Figure 17 informs the user to "remember! Wait until food becomes well-cooked, then turn of the gas stove after (Tandaan! Intayin muna maluto and pagkain, patayin ang kalan pagkaluto ng pagkain)."

Figure 16. Fire Incident VR Environments

Figure 17. Things to do to avoid fire incidents

Moreover, once the user is done doing the safety procedures in avoiding fire incidents, the system will ask the user if he/she already finished the necessary steps in a simulation then the system will display the results of what the user accomplished. In Figure 18, the actual fire simulation is presented and the user must take the proper procedures for keeping safe, going outside the house, and preventing the rapid spread of fire such as closing the door fire, looking for a wet blanket, identifying the location of fire extinguisher, and lie down to escape the fire and get outside. The upper middle picture in Figure 18 can be well understood as a "reminder (tandaan)" to "use wet towels as an alternative to preventing fires if a fire extinguisher is not available (pwedeng gumamit ng basing tuwalya upang ipangpatay ng apoy kung walang fire extinguisher)". Once the fire is controlled do not go back immediately to the house, unless the condition is good enough to check.

Figure 18. Things to do during fire incidents

Typhoon VR Simulation

The last simulation scenario is the Typhoon, the setting of the simulation is inside a house near sewage and water canals. The first part of the simulation is that the character is watching a TV set on a News Channel about the weather forecast, this part indicates to always be updated in terms of weather and do follow the tips in preparing for the upcoming typhoon shown in Figure 19. The third picture from the left list the tips before typhoon (tips bago ang bagyo)", such as "create preparation plans to flood (gumawa ng plano sa paghahanda sa baha)", " prepare the tool (ihanda ang mga kagamitan)", "prepare the survival tools for typhoon (ihanda ang survival tool para sa bagyo)", "charge the emergency devices (icharge ang mga emergency device)", "prepare the electric generator

(ihanda ang generator)", and "strengthen the roof structure and foundation of the house (patibayin at talian ang bubong at bahay)".

Figure 19. Typhoon VR Environments

After knowing the things to do in preparing for the typhoon, the user does the tips and guides such as; preparing a survival kit, charging mobile phones or radio, etc. And since the setting of the simulation is near water canals, another part of the simulation is making sure the surroundings of the house are also safe as presented in Figure 20.

Figure 20. Things to prepare before typhoon

Furthermore, this VR application will simulate the actual or during the typhoon wherein the user will now do the appropriate actions on what to do during the occurrence of typhoon like listening to the updated news, making sure the doors and windows, unplugging the sockets, and save water as shown in Figure 21. The first picture located in the upper right corner shows the different "tips during typhoon (tips habang bumabagyo)" like "listen to the radio (makinig ng radyo)", "close the following: door and windows (isarado ang sumusunod: pinto, bintana)", "unplug the electric plugs (hugutin ang mga nakasaksak sa kuryente)", and "store clean water (mag-imbak ng malinis na tubig)".

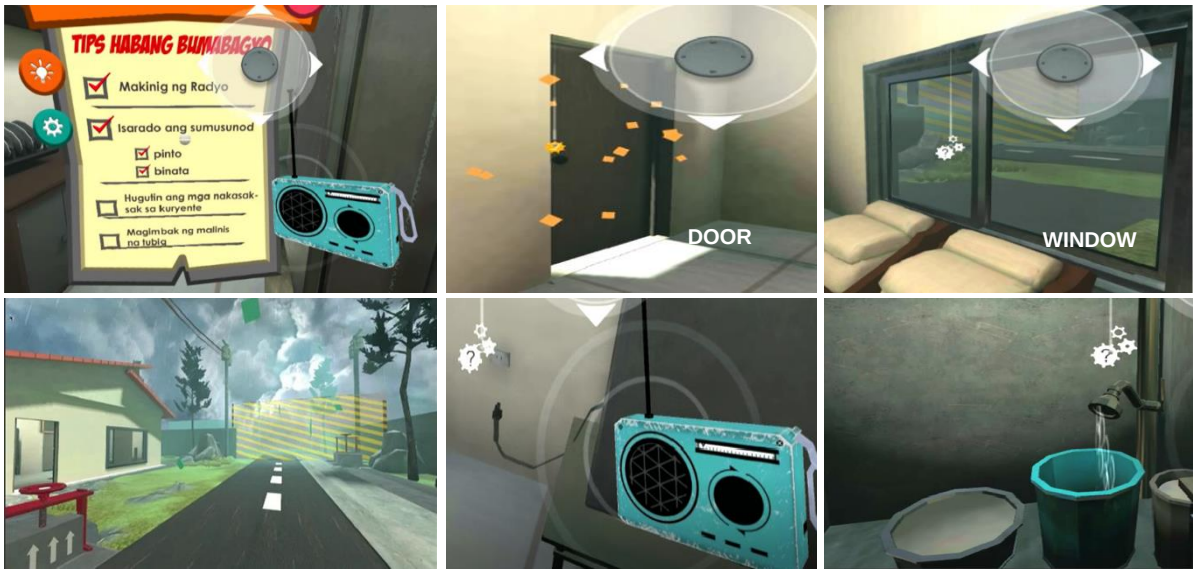

Figure 21. Simulation During Typhoon

Once the typhoon is done, users can do the "after" typhoon activities like reporting the current situation to officials and friends, reporting the fallen trees, posts, and other infrastructures to the related government respondent agencies shown in Figure 21. The first picture in the upper left corner of Figure 22 shows the "tips after typhoon (tips pagkatapos ng bagyo)" such as "report oil or gas leak (ireport and tumagas na mga langis o gas)", "report fallen trees (ireport ang tumumbang puno)", "report fallen electricity posts (ireport and tumumbang poste)". The upper right picture portrays the need to "report fallen electric posts (ireport ang mga tumumbang poste)". The last picture in the lower right corner shows the need to "report oil or gas leaks (ireport and mga tumagas na langis o gasoline)".

Figure 22. Things to do after typhoon

Every time the user will do the tasks of every different disaster simulation in BEFORE, DURING, and AFTER activities, it will display the results of what the user accomplished and the system will also determine the time how long the user will do the simulation of the disasters shown in Figure 23. The picture on the left shows the time spent in each scene: before (bago) and during (habang). The right picture shows a question that asks the user if they are done with the needed action to perform during a fire (tapos ka na bas a kailangang gawin habang may sunog?).

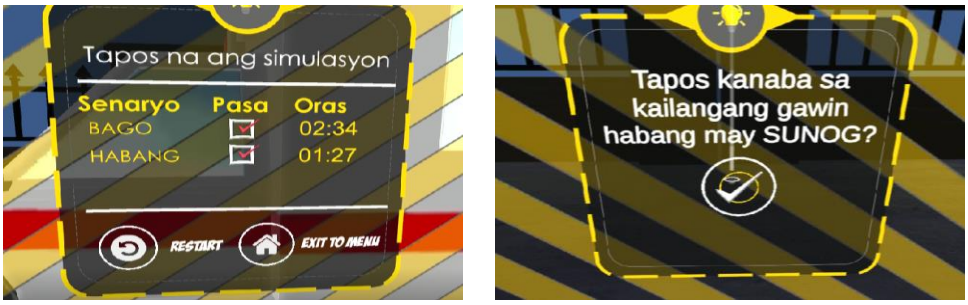

Figure 23. Time Results of Simulation

In Figure 24, at the end of every simulation, the system will show the accomplished scenarios by the user, if failed to accomplish the appropriate task the system will provide information on what will affect the people or community not doing the necessary safety procedures.

Figure 24. Sample Disaster Simulation Results

SYSTEM TEST CASING AND EVALUATION

Table 1 shows the devices used upon testing the TyFireQuake application. Android smartphones were used in the testing, namely Mobile Phone #1, Mobile Phone #2, Mobile Phone #3, and Mobile Phone #4. These mobile phones have different brands and specifications to test the full capability and flexibility of SSF mobile applications.

Table 1. List of Android phones used in testing the TyFireQuake Application

DEVICE	ANDROID VERSION	RAM	PROCESSOR
Mobile Phone #1	Q 10.0	6gb	Snapdragon 732g
Mobile Phone #2	Pie 9.1	4gb	Samsung Exynos 9610
Mobile Phone #3	Oreo 8.1	4gb	Mediatek Helio G85
Mobile Phone #4	Lollipop 5.1	3gb	Mediatek MT6750

FUNCTIONALITY TEST

Table 2 shows the summary of functionality tests by modules, the overall testing of functionality of the TyFireQuake application has passed all the testing. The mobile application's modules were successfully developed and working as the researcher expected. The total test result was 1410 from six different modules. The application can be used in two game modes, VR and thru an in-screen joystick but still with the same functionality. It consists of 3 tasks all of the activities have 10 test cases each except the

joystick movement with 40 test cases. 420 test cases have successfully passed the test case while 40 test cases have failed during the testing some parts of the Typhoon Simulation failed to perform After activity functionalities.

Table 2. Overall Functionality Test Case

Module/ Activity	**No. of Functionality Requirements**	**Total number of Test Case**	**Status**
Home	50	50	Passed
Information Guide/Help	60	60	Passed
Tutorial	120	120	Passed
Lindol (Earthquake Simulation)	340	340	Passed
Sunog (Fire Simulation)	380	380	Passed
Bagyo (Typhoon Simulation)	460	420	Passed
TOTAL	1410	1370	Passed

Table 3 shows the functionality test result for the Home activity. It is composed of the different main features and functionality of the application. All of the activities have 10 test cases each and had passed all the test cases. It shows that the home activity has passed all the functionalities that are needed.

Table 3. Summary of Functionality Test for Home Activity

Functionality	**No. of Test Cases**	**Remarks**	
		Passed	**Failed**
Information Guide/Help	10	10	0
Tutorial	10	10	0
Lindol (Earthquake Simulation)	10	10	0
Sunog (Fire Simulation)	10	10	0
Bagyo (Typhoon Simulation)	10	10	0
TOTAL	**50**	**50**	**0**

Table 4 shows the functionality test result for the Information Guide/Help activity. It is composed of guides and tips on how to use the application, 6 functions were present in it including 5 tips and a close button. All of the activity has 10 test cases each and has passed all the test cases. It shows that the information guide/help activity has passed all the functionalities that are needed.

Table 4. Summary of Functionality Test for Information Guide/Help Activity

Functionality	No. of Test Cases	Remarks	
		Passed	Failed
Tips 1	10	10	0
Tips 2	10	10	0
Tips 3	10	10	0
Tips 4	10	10	0
Tips 5	10	10	0
Close Button	10	10	0
TOTAL	**60**	**60**	**0**

Table 5 shows the functionality test result for the Tutorial activity. The application can be used in two game modes, VR and thru an in-screen joystick but still with the same functionality. Both game modes and their activities had passed all the test cases. It shows that the tutorial activity has passed all the functionalities that are needed.

Table 5. Summary of Functionality Test for Tutorial Activity

Functionality	No. of Test Cases	Remarks	
		Passed	Failed
VR Game Mode	10	10	0
Joystick Game Mode	10	10	0
Joystick Movement	40	40	0
Guide Button	10	10	0
Close Button	10	10	0
Valve	10	10	0
Door Button	10	10	0
Restart	10	10	0
Exit to Menu	10	10	0
TOTAL	**120**	**120**	**0**

SHARING TEST

The application's capability in sharing to different devices was also tested by the developers using 4 different android devices. The apk file of the application was shared using two different sharing tools namely ShareIT and Bluetooth. The TyFireQuake application has a file size of 306MB.

Table 6 shows the transfer speed of every android device used in the test, the sharing test used the Shareit application and Bluetooth in transferring the apk file of the application. Due to the large size of the app, file transfer took a lot of time mostly using Bluetooth, Mobile Phone #4 has the shortest time transferring the file via Bluetooth while Mobile Phone #2 has the fastest time transferring the file via Shareit.

Table 6. Sharing Test Results

SHARING APPS AND DEVICES	EXPECTED RESULT	RESULTS ON DIFFERENT ANDROID DEVICES			
		Mobile Phone #1	Mobile Phone #2	Mobile Phone #3	Mobile Phone #4
SHAREit	Must share the application successfully	(PASSED) 1min & 2 secs	(PASSED) 1 min	(PASSED) 1min & 3secs	(PASSED) 1min & 8secs
Bluetooth	Must share the application successfully	(PASSED) 25mins & 29secs	(PASSED) 26mins & 33secs	(PASSED) 23mins & 43secs	(PASSED) 23mins & 15secs

INSTALLATION TEST

Table 7 shows that the APK file of the TyFireQuake app was successfully installed on 4 different mobile phones. The test results show that Mobile Phone #1 has the fastest installation time of 12.94 seconds as well as an uninstallation time of 1.25 sec. Mobile Phone #4 has the slowest installation time with a result of 33.59 seconds as well as an uninstallation time of 2.95 secs.

Table 7. Installation Test Results

Activity	**Expected Results**	**Results on different Android Devices**			
		Mobile Phone #1	Mobile Phone #2	Mobile Phone #3	Mobile Phone #4
Installation	Must install the application successfully	(Passed) 12.94secs	(Passed) 14.40secs	(Passed) 13.38 secs	(Passed) 33.59secs
Uninstallation	Must uninstall the application successfully	(Passed) 1.25secs	(Passed) 2.42secs	(Passed) 1.38 secs	(Passed) 2.95secs

Table 8. Load Test Results for TyFireQuake Application

Activity/Module	**Results on different Android Devices**			
	Mobile Phone #2	Mobile Phone #2	Mobile Phone #3	Mobile Phone #4
Clicking App Icon	6.61secs	6.02secs	6.23secs	6.75secs
Clicking Guide/Help Button	21ms	21ms	32ms	41ms
Clicking Tips Button	17ms	15ms	22ms	87ms
Clicking Tutorial Button	20ms	21ms	31ms	80ms
Clicking Video Button	20ms	18ms	20ms	2.51secs
Clicking Skip Button	19ms	19ms	22ms	39ms
Clicking Menu Button	17ms	15ms	17ms	1.16sec
Clicking Lindol Button	18ms	18ms	22ms	64ms
Clicking Sunog Button	17ms	20ms	21ms	46ms
Clicking Bagyo Button	15ms	17ms	17ms	19ms
Clicking Play Button	16ms	19ms	18ms	47ms
Clicking Start Button	19ms	22ms	22ms	19ms
Clicking Play VR Mode	4.43secs	4.36secs	8.12secs	4.48secs
Clicking Play Joystick Mode	5.87secs	5.92secs	8.84secs	25.05secs
Clicking Items	1.11sec	1.10sec	1.18sec	1.23sec
Clicking Tasks (Small Gear Icon)	1.65sec	1.87sec	1.98sec	2.41secs
Clicking Task (Big Gear Icon)	2.25secs	2.44secs	2.71secs	3.12secs
Clicking Settings Button	1.68sec	1.33sec	1.75sec	1.93sec
Clicking Control Button	1.50sec	1.39sec	1.52sec	1.63sec
Clicking Restart Button	1.66sec	1.43sec	1.62sec	1.72sec
Clicking Check Button	2.87secs	2.81secs	3.09secs	4.36secs
Clicking Exit to Menu Button	1.53sec	1.55sec	1.92sec	1.88sec
Clicking Exit Button	2.06secs	1.86sec	2.55secs	2.64secs
Clicking Close Button	96ms	86sec	1.03sec	2.06secs

LOAD TEST

Table 8 shows the results of the loading test in the user part of the mobile app. Upon giving the specifications of the 4 different mobile phones, the loading and delays

only range from 0.15 milliseconds to 25.05 seconds. Mobile phone #2 leads the tests with 12 fastest loading times out of 24 this includes opening the application and using VR Game mode, it is followed by Mobile Phone #1 with 9 fastest loading times including loading time using Joystick Mode and clicking tasks. Mobile Phone #3 ranks third and as seen on the data Mobile Phone #4 performs last on the loading test, it recorded the longest time of 25.05 secs. on the loading time when using Joystick Mode.

PORTABILITY TEST

Table 9 shows that the APK file of the TyFireQuake application was successfully working on 4 different mobile phones. These mobile phones have different specifications, namely, brand, RAM, processor, and android versions. The mobile app can be installed from Android version 6 to 10 according to the developer of the mobile application.

Table 9. Portability Test Result

Device	**Specification**			**Status**
Mobile Phone #1	Q 10.0	6gb	Snapdragon 732g	Passed
Mobile Phone #2	Pie 9.1	4gb	Samsung Exynos 9610	Passed
Mobile Phone #3	Oreo 8.1	4gb	Mediatek Helio G85	Passed
Mobile Phone #4	Lollipop 5.1	3gb	Mediatek MT6750	Passed

PERFORMANCE TEST

Table 10 depicts the responsiveness of the TyFireQuake mobile application. Upon testing, the different process undergone by the android devices does not affect the performance of the mobile app which means the application can process the commands in real-time.

Table 10. Performance Test Result

Input	Process	Expected Response Time	Actual Response Time	Remarks
VR Object detection	Detect Objects	1 – 2 seconds	1 – 2 seconds	Passed
VR Task Detection	Detect the gear icon tasks	2 – 3 seconds	2 – 3 seconds	Passed
Joystick Controller	Responses movement using the screen	1 – 2 seconds	1 – 2 seconds	Passed
VR Motion Detection	Responses to movement using head movement	2 – 3 seconds	2 – 3 seconds	Passed
Home Manual Buttons	Show game guide/help	1 – 2 seconds	1 – 2 seconds	Passed

SYSTEM TESTING

For the System Testing, the application was tested based on the desired functionalities from the objectives of the project to reassure if there are missing functions to fulfill the objectives of this research as presented in Table 11.

Table 11. System Testing Result

Requirements	Process	Expected Results of Requirements	Actual Results of Requirements	Remarks
Item Detection	Identify Objects/Items	Provide pop-up notification info of the item	Provided pop-up notification item progress.	Passed
Task Detection	Identify small and large gear icon tasks	Provide pop-up notification info of the task	Provided pop-up notification of the task's progress.	Passed
Movement Recognition	Mobile phone screen responses to movement	Shows movement on the mobile screen	Showed movement and different viewing angles.	Passed
Pop-up Notifications	Notifications about tasks and warnings	Show task progress and warnings.	Showed task progress, warnings, and directions.	Passed
Guide Controls	Textual information	Provide help and tutorials.	Showed game tutorials and tips.	Passed

CONCLUSIONS AND RECOMMENDATIONS

The study aims to explore the effectiveness of the design of disaster preparedness simulation training through Virtual Reality (VR) technology. It serves as an assessment tool for measuring the competency and ability of the children to engage and respond efficiently in disasters. Compared to the traditional teaching methods, learning through virtual reality fosters numerous advantages. One of the main advantages of virtual training is its ability to provide a safer and more realistic training environment. The design involves simulated real disaster environments such as fire, typhoons, and earthquakes that could be beneficial in equipping the children with sufficient knowledge and skills in responding to these emergencies. In this study, the design was found to be a replication of real disaster environments which can potentially be effective and sufficient in training children without causing immense physical danger.

In other words, this virtual reality (VR) disaster preparedness simulation training program for children is designed to help them respond effectively and safely to disasters.

The advantages of virtual training over live training are numerous and can enable people to practice various skills in a virtual world. This study shows that virtual training can help individuals develop the necessary skills to respond to disasters and minimize their risk.

For further study, the developed mobile application can be implemented by the government agency emergency response team as a tool for disseminating awareness of disasters, especially to the children. Moreover, add more controllable simulations, provide direct feedback to the user, and apply a database to collect more information and behavior of the user that can be utilized to produce better insights in formulating good strategies and activities for promoting awareness of disaster prevention.

IMPLICATIONS

Due to the uncontrolled impacts of global warming, the weather started to change and disasters occur more frequently. Failure to mitigate the impacts of these events may lead to the destruction of properties and the lives of people. One of the main causes of severe damage is the lack of knowledge and skills regarding disaster preparedness, especially among children. Thus, the development of TYFIREQUAKE virtual reality simulation of fire, earthquake, and typhoon scenarios using Virtual Reality (VR) is a major step toward addressing the issue related to the lack of disaster preparedness among children.

The development of TYFIREQUAKE virtual reality simulation is significant in the field of disaster response. It will benefit the communities, especially the children in alleviating the lack of knowledge and skills. They will be equipped with proper strategies in protecting their lives and others. The developed program consists of features that will train the children to identify the possible safe places, maximize the available resources, and action plans for recovery after the disasters. Additionally, the significant effects can be optimized if children will use the program for several training sessions properly. In other words, this is a suitable training tool to maximize the capacity of children to effectively respond to typhoons, fires, and earthquakes.

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