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The development of a virtual reality adventure game to prepare for a tsunami disaster

ABSTRACT

This research aimed to study and analyse the interaction between humans and a tsunami disaster simulation. Besides, it aimed to develop a virtual reality (VR) adventure game in regard to preparing for a tsunami disaster caused by an earthquake. It also assessed the effectiveness of virtual reality (VR) through three perceptions, namely visual perception, auditory perception, and kinesthetic perception with the connection between the human user and the Oculus quest 1 (VR glasses) to create virtual reality that was easy to understand and reflected interesting storytelling accompanied by beautiful patterns. The research objectives were 1) to study, collect, and analyse data related to the concept of creating virtual reality (VR), 2) to design and create virtual reality (VR) adventure game, and 3) to test and assess the perceptions of virtual reality (VR) to prepare for a tsunami disaster caused by an earthquake. The results of studies and analysis based on the learning style theory and participants' behaviour showed that the behaviour was often instilled from experiences that they had gained. This created clarity in the role of the participants and helped them learn and practice using virtual reality technology in training and deal with tsunami disasters caused by earthquakes. The results of the perception assessment of the virtual reality (VR) prototype, overall, indicated that the adventure game in a virtual reality (VR) setting to prepare for a tsunami disaster caused by an earthquake was feasible for use.

KEY WORDS
Virtual reality, tsunami disaster, adventure game, learning style

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Introduction

"Preparing for natural disasters with modern media" expresses the integration of science technology and creativity. It also develops the media to be up-to-date and clearly reach the target group in order to adapt and respond to changing environments. Empowering modern media with science technology and creativity will lead to the production of interesting media that must meet the needs of today's users and turn into innovations that lead to increasing economic added value in the future.

These days, there are various natural disasters occurring continuously in Thailand and in our world. These disasters impact humans and living things both directly and indirectly. Therefore, it is necessary to study and learn about various types of natural disasters in order to understand the nature of the occurrence and prevention of natural disasters that will occur, especially the provision of disaster education to teachers and educational personnel in risky areas. As a result, they will have knowledge and understanding of various natural disasters and can survive when disasters strike as well as pass on knowledge to others correctly (Pananont, 2018).

According to Moussa (2014), learning styles play a crucial role in the learning process. There are three main characteristics of learners, namely visual learners, auditory learners, and kinesthetic learners. Visual learners are those who best learn through visual stimuli such as images, colored depictions, and media. Auditory learners are those who prefer learning

through listening, and kinesthetic learners are those who best learn through movement. It can be said that understanding the characteristics of learners can absolutely enhance their overall learning process.

Virtual reality (VR) is a simulation of the environment purveyed under the atmosphere of virtual reality. The user perceives through devices called VR glasses so that he/she does not need to be in a real-world situation. For example, VR is used in an experimental design for collecting data on human behaviour and emergency response in a virtual reality subway environment (Sharma et al., 2014). This is based on the conceptual framework in the Narrative Mode which is linked to the user's behaviour, experience, enjoyment, and interest (Aylett & Louchart, 2003). Also, it is related to the theory of learning styles through three perceptions, namely visual perception, auditory perception, and kinesthetic perception. It is conducted by separating the user from the current environment to enter the environment created with a 3D visualization program. As a result, the user has actually entered that environment designed and created, which is in the form of virtual reality (VR). The researchers found that storytelling theory plays a key role in the link between the learning of the target group's behaviour and the various elements of virtual reality, from the beginning of the research to the perception of the target group. This is done continuously and systematically for effective and optimized work and can be applied to the theory of development in virtual reality. The researchers investigated the key factors that could be used to create perceptions in the use of virtual reality technology by determining the role to be appropriate according to the situation at that time in order to be connected to the perceived experience.

Koh Yao District, Phang Nga Province, is considered a world-class tourist destination since there are more and more tourists coming in each year. However, Koh Yao District is a vulnerable area to various disasters, including tsunamis.

Therefore, it must be prepared to cope with these disasters. There is disaster preparedness in various aspects, including training and educating the community and related agencies, and in both the public and private sectors. This aims to assist local residents and tourists in securing life and property. The researchers were interested in studying tsunamis caused by earthquakes and coping with tsunamis currently in order to find ways to create virtual reality to prepare for a tsunami disaster for people in the area. This can be done by applying the concept of disaster management with virtual reality (VR) technology. This study will help Koh Yao district, Phang Nga Province, to have the tool to prepare for the event of future tsunami disasters in the area.

Research objectives

1. To study, collect, and analyse data related to the concept of creating virtual reality (VR) to prepare for a tsunami disaster caused by an earthquake.
2. To design and create virtual reality (VR) adventure game to prepare for a tsunami disaster caused by an earthquake.
3. To test and assess the perceptions of virtual reality (VR) to prepare for a tsunami disaster caused by an earthquake.

Literature Review

The researchers examined, synthesised, and analysed the patterns/elements of the aforementioned virtual reality technologies and chose the elements for the creation of a virtual reality (VR) setting to prepare for a tsunami disaster caused by an earthquake that consisted of image, narrative mode, virtual reality graphical elements, simulation environment, colour, and roles and rules. The researchers also examined all elements of virtual reality technologies suitable for creating virtual reality (VR) to prepare for a tsunami disaster caused by an earthquake as shown in Table 1. Also, the simulation design for virtual reality is shown in Figure 1.

From Table 1, the researchers selected and compared the elements of virtual reality technology in 8 articles in order to identify their characteristics, strengths, and weaknesses. The storytelling and visual features created by various techniques were the basic tools for developing an adventure game in this present study. In addition, the differences under the framework of the theory of learning styles through three perceptions (i.e., visual perception, auditory perception, and kinesthetic perception) in relation to the interaction between the human body and the Oculus quest 1 (VR glasses) were identified. The obtained data were used to create virtual reality in this study, thus aiming to have the inclusion of interesting storytelling, beautiful design, and communicating to the user clearly. The data are summarised in Table 2.

From the virtual reality design table, the main focus is finding data in order to determine the action story and the relationship of time to send information to the operating system. This depends on the role assigned and the requirements of the virtual reality designer to link the data through the process. As a result, the participants would gain knowledge and understanding of the situation in which the designer had set the goals which were already used and established in real-world applications, such as knowing initial survival in the event of a tsunami. The process of creating virtual reality is shown in Figure 2 below.

Table 1 (part 1)

A summary of the elements of virtual reality

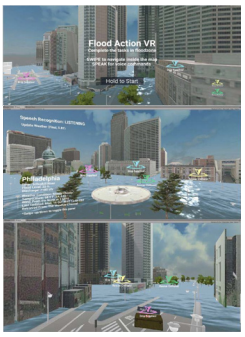
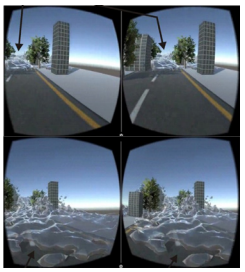
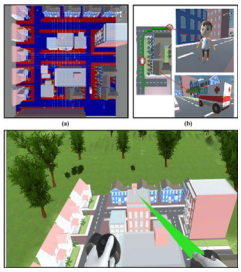
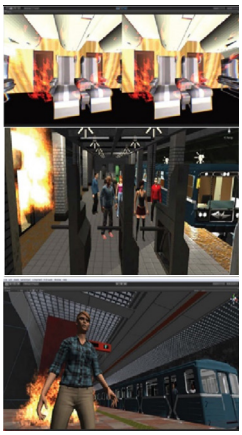
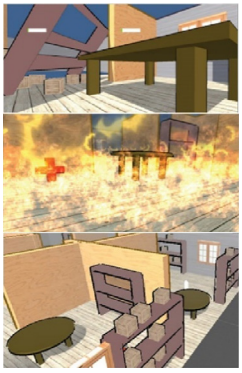
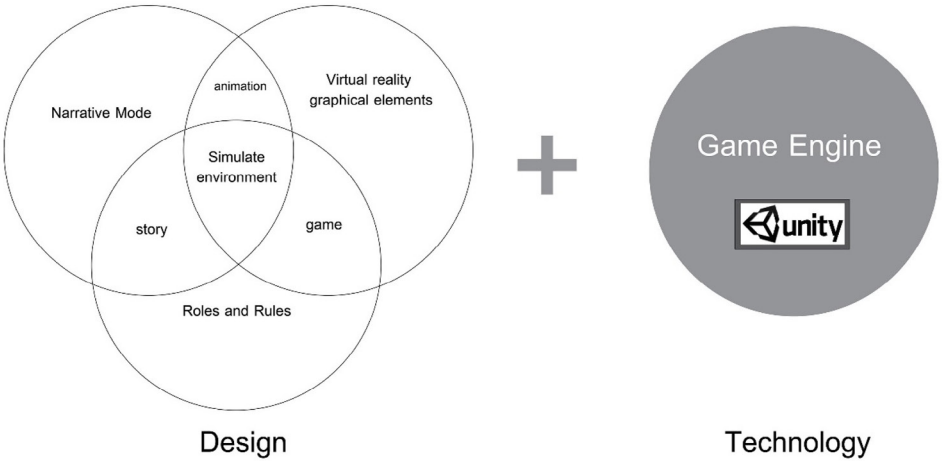
Title/Author	Image	Content	Strength	Weakness	How it relates to the present research
1. Flood Action VR: A Virtual Reality Framework for Disaster Awareness and Emergency Response Training (Sermet & Demir, 2019)	 Recreated from satellite imagery and mapped to the ArcGIS 3D model	This article presents a simulation of a flood situation.	It creates presentation scenes from a real situation to raise awareness about a disaster risk in the community.	The texture of the object in the picture is not very realistic.	The image can be used to experiment with designing virtual reality that looks simple and uncomplicated.
2. Tsunami Run-Up Simulation Using Particle Method and its Visualization with Unity (Saitoh, Noguchi & Inoue, 2018)	 Recreated from the MAYA 3D program.	This paper presents virtual reality simulation of an urban area with some buildings affected by the tsunami.	It creates presentation scenes from a real situation	The image shown still does not look realistic due to old equipment.	The image can be used to experiment with designing virtual reality that looks simple and uncomplicated.
3. 3D visualization tool for Virtual models of natural disasters (Pajorová et al., 2007)	 Created from 3D ortophotomap	This paper presents a tool to create 3D visualization in order to show the results of simulating various natural disasters such as severe fires, erosion, floods, or landslides.	It was the first research that used 3D visualization of natural disasters.	The emphasis is put on the basic use of virtual reality simulation of a landscape.	Creation of a 3D model of a city that was affected by disasters in the form of 3D landscape architecture using grid computing.
4. A Conceptual framework for 3D Visualisation to support urban disaster management (Kemec, Duzgun & Zlatanova, 2009)	 Created from 3D Lowpolygon	This paper presents a 3D city simulation built for earthquakes.	The creation of urban mode based on Level of Detail (LoD) concept. Most details in the scene are done by adding the objects to the game in order to make the scene realistic.	The emphasis is put on the basic use of a virtual reality simulation of the landscape in the form of boxes.	Creation of a 3D simulation of a city that was affected by disasters in the form of Lowpolygon 3D.

Table 1 (part 2)

A summary of the elements of virtual reality

Title/Author	Image	Content	Strength	Weakness	How it relates to the present research
5. A Virtual Reality Application for Disaster Response Training (Nguyen, Jung & Dang, 2019)	 Created from Unity3D	This article presents an in-process virtual reality called VRescuer to help train trainees and familiarize themselves with various disaster situations in the city. The scenarios are created with rescue service, ambulance, and rescuers.	It can allow users to participate in virtual reality more clearly with the Oculus Rift device.	The image shown is cartoon-like. It's not very realistic.	VR to train rescuers in disaster response in a simulated environment.
6. Immersive Virtual Reality Environment of a Subway Evacuation on a Cloud for Disaster Preparedness and Response Training, (Sharma et al., 2014)	 Created from 3D Studio Max	This paper presents an experimental design approach in order to collect data on human behaviour and emergency response in a subway environment.	The image is more realistic and clearer with the Oculus Rift device.	The texture of the object in the picture is not very realistic.	Using the knowledge gained from different situations can help people be better prepared to make decisions in emergency situations.
7. Minmin Escapes from Disaster: An Oculus Rift Disaster Simulation Game (Dumol et al., 2014)	 Created from 3D Lowpolygon	This article is a virtual disaster simulation game for teenagers. The research team focuses on adolescents because knowing how to prepare for a disaster should be learned as quickly as possible. It is a disaster escape of Minmin.	Storytelling in a game is fun. The goal of the game is to teach children what to do during a disaster in a fun manner by being in virtual situations.	The image shown is cartoon-like. It's not very realistic.	It prepares for realistic disaster by allowing players to see the calamities that happen around them. This can teach children better on how to survive a disaster.
8. Towards a narrative theory of virtual reality (Aylett & Louchart, 2003)	-	This article points out how VR works with storytelling theory. This affects how to make the story interesting.	The way to tell a story makes it interesting and connect to VR technology. This creates a new experience, allows enjoyment, and sparks interest.	-	It shows how to tell an interesting story with a simulated event.

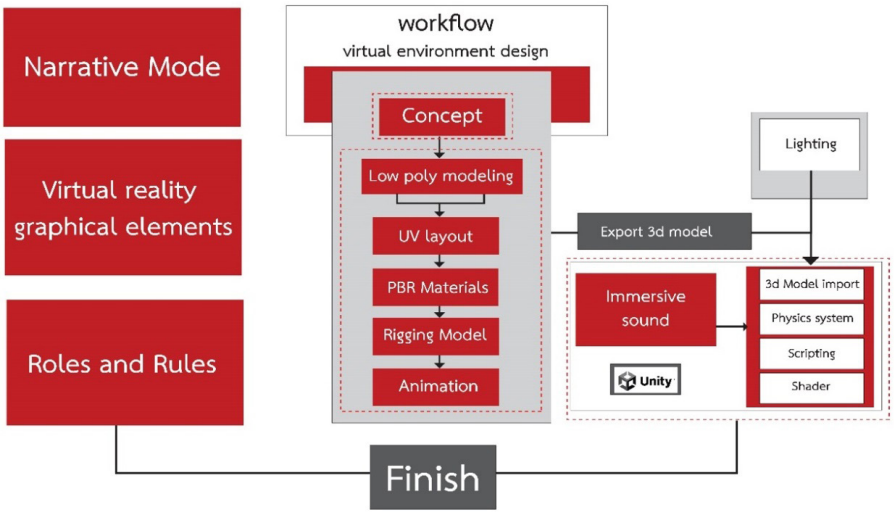


» **Figure 1:** *Simulation design for virtual reality*

Table 2

A comparison of the elements of 8 virtual reality simulations and the development of a virtual reality (VR) adventure game to prepare for a tsunami disaster designed in this present study

Elemental properties of 8 virtual reality simulations	An application of 8 virtual reality simulations to the design of the VR simulation to prepare for a tsunami disaster designed in this present study
1. Image	1. The designed image is Low polygon 3D Model PBR Materials. The model has a low polygon number, so the model is not heavy, focusing on the use of virtual reality with a texture suitable for use in designing games and virtual reality without complex details.
2. Narrative mode	2. There is no difference in this point. The way to tell a story to be interesting is connected to VR technology. It creates a new experience, allows enjoyment, and sparks interest.
3. Virtual reality graphical elements	3. There is a creation of a real environment into virtual reality through the perception of sight, objects, and scenes by cutting players off from the current environment in order to enter an interesting simulated image connected with VR technology.
4. Simulation environment	4. There is no difference in this point. The perception of sight and touch can be applied to sound design to match the environment.
5. Roles and rules	5. The behaviour of the participants is often instilled in the experiences they have gained. This creates clarity in the role of the participants and helps them to learn and practice using virtual reality technology in training and dealing with tsunami disasters caused by earthquakes. Therefore, it must be safe.



» **Figure 2:** *The process of creating virtual reality*

Research Method

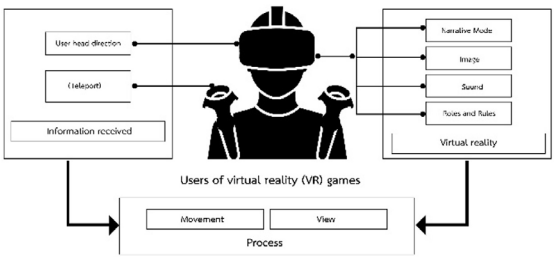
This research was conducted to study and analyse the interactions between humans and the tsunami disaster simulation in order to develop a virtual reality (VR) adventure game to prepare for a tsunami disaster caused by an earthquake. The research process is as follows.

1. Literature review: The secondary data were collected by gathering and analysing documents, textbooks, books, theories, research studies, and related academic articles, such as "Narrative Theory", "Learning Style Theory", and "Disaster Management Theory" as a conceptual framework for this research.

2. Data collection: In this study, the data were collected in three phases.
Phase 1: The data collection was to review documents, textbooks, books, theories, research papers, and academic articles related to this present research and interview key informants according to their expertise. This could be used as a guide for the creation of a virtual reality (VR) tool to prepare for a tsunami disaster.
Phase 2: After the research objectives and rationale for virtual reality design were determined, the design process was another very important step in designing virtual reality. The researchers selected the appropriate elements to design virtual reality. The process of designing virtual reality consisted of data collection, technological limitations, the concept of art-play, key features screens, player behaviour, and bringing design principles to design virtual reality.
Phase 3: After finishing the design process, the researchers tested and assessed the perceptions of virtual reality (VR) to prepare for a tsunami disaster caused by an earthquake. The participants were divided into two main groups. The first group was composed of three designers in the field of new media and two experts in the field of tsunami disasters. These participants were chosen through purposive sampling. The second group was composed of a group of 30 people who experienced a tsunami disaster in Koh Yao District, Phang Nga Province. They were chosen by convenience sampling and were divided into three groups according to their ages: 1) a group of people aged 19-25 years, 2) aged 26-40 years, and 3) aged 41-60 years. In this study, the research instruments included two sets of instruments: 1) a Likert-scale questionnaire and in-depth interview regarding elemental properties of virtual reality and 2) a Likert-scale questionnaire regarding the perceptions of virtual reality (VR) to prepare for a tsunami disaster. As for the group consisting of the designers and experts, a Likert-scale questionnaire and in-depth interview regarding the elemental properties of virtual reality were conducted. As for those who experienced a tsunami disaster, the questionnaire regarding the perceptions of virtual reality (VR) to prepare for a tsunami disaster was conducted by focusing on learning styles and perception evaluation.

3. Data Analysis: Regarding analysing the elements of virtual reality technology above, the researchers chose the elements of creating virtual reality (VR) to prepare for a tsunami disaster caused by an earthquake that consisted of image, narrative mode, virtual reality graphical elements, simulation environment, colour, and roles and rules. The researchers examined all elements of virtual reality technology to be suitable for creating a virtual reality (VR) environment to prepare for a tsunami disaster caused by an earthquake, thus selecting the visual characteristics of Low polygon 3d Model PBR Materials. This model was chosen since it is with fewer polygon numbers which is not weighty, emphasizing the use of virtual reality with a texture, suitable for use in designing games and virtual reality without complex details, and being in line with technology limitations to create a clear simulation environment. For the reasons mentioned above, the researchers concluded a specific guideline for creating virtual reality (VR) to prepare for a tsunami disaster with the elements of the image, narrative mode, virtual reality graphical elements, simulation environment, colour, and roles and rules. For the creation of virtual reality (VR) to prepare for tsunami disasters, the limitations of technology for creating a simulated environment should be clearly understood.

4. Design: It was a synthesis of variables obtained from the given analysis in order to determine the guidelines for designing a virtual reality (VR) environment to prepare for a tsunami disaster. During the design process, the data were collected from a research sample of the pilot study prior to actual use. The data gained were then analysed, synthesised, and used as the virtual reality (VR) model to prepare for a tsunami disaster, using Lowpolygon PBR material Oculus quest 1 as shown in Figure 3.



» **Figure 3:** *The working system of the VR simulation game to prepare for a tsunami*

5. Assessment: It was to assess the perceptions of virtual reality (VR) to prepare for a tsunami disaster. The sample group using media experimented with two types of games, namely 1) a virtual reality (VR) prototype to prepare for a tsunami disaster using Low polygon VR Cardboard in which the image was used to test the design of virtual reality that was simple, not complex, and 2) a virtual reality (VR) prototype to prepare for a tsunami disaster that was developed and had used Low

» **Figure 4:** *Lowpolygon VR Cardboard (up) Low polygon PBR material Oculus quest 1 (down)*

» **Figure 5:** *Virtual reality that the users see and the researcher using the Oculus Quest 1 device*

polygon PBR material Oculus quest 1, shown in Figure 4, in which the image was used to test the design of virtual reality that was simple, not complex, but the image was realistic. The questionnaire was then completed.

6. Final design: The final design was the reflection of the results obtained from the evaluation and identification of defects of programs and devices. It was then developed in order to get the complete game. Figure 5 shows virtual reality that the users see and shows the researcher using the Oculus Quest 1 device.

Results and Discussion

According to Research Objective 1 aiming at studying, collecting, and analysing data related to the concept of creating virtual reality (VR) to prepare for a tsunami disaster caused by an earthquake, it was found that the learners could learn from three types of perceptions, that is, visual perception, auditory perception, and kinesthetic perception. Additionally, they could determine the elements in each section appropriately. This makes the creation of virtual reality (VR) tools useful and interesting. This result is consistent with Denpaiboon & Pongpisit (2011) who note that, for creating participants' behaviour, the behaviour of the participants is often instilled in the experiences they have gained. Making a simulation game is a simulation in which some or all of the similarities or references to decisions are made in real situations. Roles and rules of play are defined in order to achieve balance in terms of player, simulation, and game by connecting humans and devices. On the basis of creating a virtual reality (VR) environment, the storytelling must be interesting. Moreover, the pattern needs to be beautiful and easy for the user to understand.

Designers must bring the elements mentioned above to fit the story and use it for maximum benefit. From Research Objective 2 aiming at designing and creating a virtual reality (VR) adventure game to prepare for a tsunami disaster caused by an earthquake, the researchers designed and created virtual reality (VR) design guidelines and determined the design concepts. The concept of simulation requires interactions between humans and simulations, including other elements. Sharma et al. (2014) discusses the principles of designing virtual reality environments for training that using the knowledge gained from various situations helps people to be better prepared for decision-making in emergency situations.

According to Research Objective 3 aiming at testing and assessing the perceptions of virtual reality (VR) to prepare for a tsunami disaster caused by an earthquake, the results are as follows.

Regarding elemental properties of virtual reality, it was found that, based on the interview data with the experts, the stories, actions, and relationships in the game were connected, and they provided a connection of information very well. The participants could also gain knowledge and understanding of the situation well. Also, the information could be easily accessed and communicated through virtual reality that was created based on the elements in a virtual environment. Moreover, the designed images were simple, and the texture was suitable for use in game design. The stories were told through simulated events and made the players feel they were in the real world. They responded to the experience they gained in the game, and they could use this knowledge in various situations. This would help the players to be better prepared for making decisions in emergency situations. In terms of virtual reality graphical elements, people, objects, and scenes in the game were made interestingly. The simulation environment was created clearly, and it provided knowledge through the media of infographics. Additionally, exciting sounds were added in order to increase the perception of virtual reality. As for roles and rules, the players understood their roles within the game and could play a role appropriately in that virtual reality environment. This made the players involved and aware of the magnitude of the problem. This was a learning process that could be applied in the real world.

As for the Likert-scale questionnaire regarding the perceptions of virtual reality (VR), it was revealed that, in terms of appropriateness, the image and simulation environment in the game was rated at the highest level ($\bar{x}$ = 4.6, S.D. = 0.54). It was followed by narrative mode ($\bar{x}$ = 4.2, S.D. = 0.44), roles and rules ($\bar{x}$ = 4.0, S.D. = 0.71), and virtual reality graphical elements ($\bar{x}$ =3.6, S.D. = 0.89), respectively.

Regarding the perceptions of virtual reality (VR) to prepare for a tsunami disaster, focusing on learning style and perception evaluation, the results showed that, in terms of learning style, most respondents had a high level of visual perception ($\bar{x}$ = 3.71, S.D. = 0.81). It was followed by auditory perception ($\bar{x}$. =3.4, S.D.=0.80) and kinesthetic perception ($\bar{x}$=2.99, S.D.=0.76), respectively. This indicates that most respondents in this study were visual learners who best learned through seeing the information presented as visual images according to Moussa's (2014) learning styles. As for perception evaluation, it was found that most respondents had a high level of virtual reality (VR) perception ($\bar{x}$ = 3.83, S.D. = 0.38). It was followed by other types of virtual reality environment (VR) design work, such as training and warning ($\bar{x}$ = 3.79, S.D. = 0.41).

» **Figure 6:** *An infographic video clip with specific words conveying the issue of perception to the respondents*

It should be noted that, to avoid misunderstanding, the researchers described the presentation of an infographic video clip with specific words that conveyed the issue of perception to the respondents as shown in the figure below. As a result, the respondents had an understanding of the issue. The simulation game would be able to help in transferring expertise and knowledge as well as helping to manage new expertise to the player.

One interesting finding in this study was that a group of people aged 41-60 years argued that they could not keep up with technology and avoided using applications that did not match their daily lives. They did not respond to the virtual reality (VR) that the researchers designed. Most of them argued that virtual reality (VR) technology was not suitable for them. This lends support to Dumol et al. (2014) who point out that, for a virtual reality disaster simulation game for adolescents, the research team focuses on the adolescent group because knowing how to prepare for disasters should be learned as early as possible.

Based on the above findings, the respondents who did not respond to the perception of virtual reality (VR) to prepare for a tsunami disaster were able to perceive the virtual reality (VR) environment in the form of storytelling. The people who were in the age range of 19-25 years and 26-40 years were those who told and narrated to a group of people aged 41-60 years since some of them were in the same community and family. Therefore, storytelling was another way of perception.

Conclusion

This research studied and analysed the interaction between humans and a tsunami disaster simulation in order to develop an adventure game in virtual reality (VR) to prepare for a tsunami disaster caused by an earthquake. Also, it assessed the effectiveness of virtual reality (VR) under Moussa's (2014) Theory of Learning Styles through three perceptions, namely visual perception, auditory perception, and kinesthetic perception in connection between the human user and the utilization of Oculus quest 1 (VR glasses) to create virtual reality. It was revealed that the storytelling was interesting, and it specifically involved beautiful patterns. This makes the simulation game easy to understand. This research successfully designed and created an adventure game in a virtual reality (VR) setting to prepare for a tsunami disaster caused by an earthquake. Regarding the assessment of the perceptions of virtual reality (VR) to prepare for a tsunami disaster caused by an earthquake, it was found that the behaviour was often instilled from experiences that they had gained. This created clarity in the role of the participants and helped them learn and practice using virtual reality technology in training. As a result, they could prepare and deal better with tsunami disasters caused by earthquakes. Overall, this virtual reality (VR) adventure game to prepare for a tsunami disaster caused by an earthquake is feasible for use.

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